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(54) Title: DIAGNOSTIC TESTS FOR A NEW SPIROCHETE, BORRELIA LONESTARI (57) Abstract Bites from <i>Amblyomma americanum</i> , a hard tick, have been associated with a Lyme disease-like illness. Through use of the polymerase chain reaction, it was discovered that the spirochete was a <i>Borrelia sp.</i> but distinct from other known members of this genus, including <i>B. burgdorferi</i> , the agent of Lyme disease. Species-specific differences in gene sequences, e.g., of the flagellin protein, the flagellin gene and the 16s rRNA gene between the new <i>Borrelia</i> species and previously known species provide compositions and methods for determining the presence of this new spirochete, for providing evidence of past or present infection by this spirochet in animal reservoirs and humans, and for use in treatment.		

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DESCRIPTIONDIAGNOSTIC TESTS FOR A NEW SPIROCHETE,
BORRELIA LONESTARI

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1. Field of the Invention

The present invention relates generally to the fields of infection and disease. More particularly, it concerns the identification of a new spirochete carried by the hard tick, *Amblyomma americanum*, found by the present inventor to be associated with a Lyme disease-like illness. Most particularly, the invention provides compositions, methods, and kits for the identification and diagnosis of the new spirochete and for disease prevention or treatment.

2. Description of the Related Art

A paradox about Lyme disease is the report of this tick-borne infection from areas in which transmission of the etiologic agent, *B. burgdorferi*, has not been documented (Sigal et al., 1991; Barbour et al., 1993). This phenomenon has been reported from, e.g., Georgia and Missouri, but may be common in other parts of the southeastern and south-central United States (Centers for Disease Control and Prevention, 1989; 1991) and other countries. The Lyme disease-like illness is a localized, expanding circular skin rash, sometimes succeeded by persistent, debilitating systemic symptoms (Masters, 1993; Donnell, 1992). Many of the patients with this illness have had negative serologic assays for antibodies to *B. burgdorferi*, a finding that has fueled a controversy about so-called "seronegative Lyme disease" (Sigal et al., 1991; Barbour et al., 1993). Although *Ixodes scapularis* ticks, the usual vector of the Lyme disease agent, has been identified in some of these

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geographic areas, the more commonly reported exposure for these patients has been to another hard tick, *A.*

americanum, known as the "Lone Star tick" (Centers for Disease Control and Prevention 1989; 1991; Masters, 1993; 5 Donnell, 1992). One conclusion from these observations is that the disease is caused by something other than *B. burgdorferi* and that the vector of the putative agent is *A. americanum* (Maupin et al., 1992).

10 The incompetence of *A. americanum* as a vector of *B. burgdorferi* has been documented (Piesman et al., 1988; Mather et al., 1990; Mukolwe et al., 1992; Ryder et al., 1992). Nevertheless, there have been descriptions in these ticks of spirochetes that cross-react with 15 antibodies to the Lyme disease agents (Maupin et al., 1992; Schulze et al., 1984). Until the discovery of *B. burgdorferi* and related *Borrelia* species in *Ixodes* spp. ticks a decade ago, *Borrelia* spp. had almost exclusively been found in soft or argasid ticks (Barbour et al., 20 1986).

Reports from several locations in the southeastern and south-central regions of the United States indicate that this Lyme disease-like illness, which is apparently 25 ameliorated by antibiotics, is associated with bites by the Lone Star tick (Centers for Disease Control and Prevention, 1989; 1991; Masters, 1993; Donnell, 1992). *A. americanum* is a common person-biting tick in these areas (Cooney et al., 1974; Koch et al., 1980; Hair 30 et al., 1986; Bloemer et al., 1990). Its usual hosts are white-tailed deer, medium-sized mammals, and ground-feeding birds; rodents are only rarely infested by *A. americanum*. The tick's distribution extends at least from west-central Texas to Florida and north to Rhode 35 Island (Cooney et al., 1974; Koch et al., 1980; Hair et al., 1986; Bloemer et al., 1990).

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Numerous references in the literature relate to aspects of diagnosing and treating Lyme disease. For example: i) U.S. Pat. No. 5,279,938 relates to a nucleotide sequence of a recombinant clone containing a specific segment of *Borrelia burgdorferi* (Bb) DNA, the causative agent of Lyme disease; ii) an abstract by Barthhold (WPI Acc. No.: 92-041321/05) relates to OSPA polypeptides immuno-reactive with antibodies generated by the spirochete *Borrelia burgdorferi*; iii) The Weisburg world patent publication relates to nucleic acid fragments that are used to detect the etiological agent of Lyme disease, *Borrelia*; iv) The Oliver et al. (1993) abstract relates to a study of the isolation and transmission of the Lyme disease spirochete; v) The Berland et al. (1991) abstract relates to the characterization of a 41 kDa flagellin antigen of *B. burgdorferi*; vi) The Mukolwe et al. (1992) article relates to attempts to transmit the *B. burgdorferi* (Bb) spirochete to three different ticks, one of these being the *Amblyomma americanum* tick. The test results report transfer of the Bb spirochete only to *Ixodes scapularis* ticks.

Although there is much known about Lyme disease, there are currently no means of identification of the new spirochete associated with the aforescribed Lyme disease-like pathology and further, no means of diagnosis of infection, compositions for clinical tests, or laboratory assays for diagnosing a patient exhibiting Lyme disease-like symptoms but testing negative for Lyme disease. Compositions and methods for treatment are, likewise, absent.

SUMMARY OF THE INVENTION

The present invention provides compositions, methods, and kits for the detection of a new spirochete

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that is associated with a Lyme disease-like illness. The compositions are based on *Borrelia lonestari* sp. nov.-specific biological components, including DNA, RNA and proteins. For example, *Borrelia lonestari* sp. nov.-specific allotypes or combination of allotypes of the flagellin protein, or a *Borrelia lonestari* sp. nov.-specific allele or combination of alleles of the flagellin or 16s rRNA genes of the new spirochete are provided.

The allotypes and alleles of the present invention have been determined by nucleic acid sequencing of portions of the flagellin and rRNA genes from this new spirochete. Detection of a species-specific amino acid or nucleotide as defined herein, or a species-specific combination of amino acids or nucleotides as defined herein, in a subject sample is indicative of infection with *Borrelia lonestari* sp. nov.

In terms of genes that encode proteins, "species-specific allotype" or "species-specific amino acid" or "species-specific epitope" means an amino acid of *B. lonestari* sp. nov. that is different at a particular position of a protein, such as the flagellin protein, to the amino acid at that position of the protein of other *Borrelia* species, especially those species needing to be distinguished from *B. lonestari* sp. nov. Table 1 provides a listing of species-specific amino acids of this new spirochete in the context of the amino acid sequence of SEQ ID NO: 2.

"Species-specific combination of allotypes" or "species-specific combination of amino acids" or "species-specific combination of epitopes" is a combination of amino acids of a protein, such as the flagellin protein, of *B. lonestari* sp. nov. from Table 1 that is not represented in any of the, e.g., flagellin

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proteins of other *Borrelia* species, especially those species needing to be distinguished from *B. lonestari* sp. nov. Table 1 also provides a listing of amino acids that may be combined with each other to form a combination
5 that is unique to *B. lonestari* sp. nov. in the context of the amino acid sequence of SEQ ID NO: 2.

In terms of genes that encode any *B. lonestari* sp. nov.-specific biological component, "species-specific
10 allele" or "species-specific nucleotide" means a nucleotide of *B. lonestari* sp. nov. that is different at a particular position, e.g., of the flagellin gene sequence or 16s rRNA gene sequence, from the nucleotide at that position of other, e.g., flagellin gene sequences
15 or 16s rRNA gene sequences of *Borrelia* species, especially the *Borrelia* species that need to be particularly distinguished, like *B. burgdorferi*. Tables 2 and 3 provide a listing of species-specific nucleotides of this new spirochete in the context of SEQ ID NO: 1
20 and 3.

"Species-specific combination of alleles" or "species-specific combination of nucleotides" is a combination of nucleotides in the genome, as exemplified
25 by the flagellin gene and the 16s rRNA gene, of *B. lonestari* sp. nov. from Table 2 or 3 that is not represented in the genome, e.g., in any of the flagellin gene sequences or 16s rRNA gene sequences, of other *Borrelia* species. Tables 2 and 3 provide a listing of
30 nucleotides that may be combined with each other to form a combination that is unique to *B. lonestari* sp. nov. in the context of SEQ ID NO: 1 and 3.

Species-specific flagellin amino acids of
35 *B. lonestari* sp. nov. are listed in Table 1 as the underlined residues in the column B1 and include Val 24, Thr 65, Ala 67, Phe 90, Ser 91, Thr 92, Gly 99, Val 103,

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Pro 119, Ile 126, Ser 127, Ile 136, Ala 140, Thr 144, Asp 174, and Ile 191, of SEQ ID NO:2.

Species-specific flagellin nucleotides of
5 *B. lonestari* sp. nov. are listed in Table 2 as the
underlined nucleotides in the column B1 and include G 70,
G 96, T 141, A 193, G 199, G 228, A 231, T 269, C 270, T
271, A 273, A 300, T 308, G 315, A 376, G 380, A 406,
G 418, G 423, G 505, A 510, G 546, T 572, and C 603 of
10 SEQ ID NO:1.

Exemplary species-specific combinations of amino
acids where the amino acid itself is not species-specific
are found by comparing the amino acids of Table 1 and
15 finding a combination of B1 amino acids that is not
represented in any of the other species listed in the
context of the flagellin amino acid sequences of these
organisms. Examples include: amino acid #s 41 and 46,
46 and 108, 117 and 153, 130 and 153, 46 and 147, 152 and
20 169, 152 and 171, and 46 and 196 of SEQ ID NO:2, for
example.

Of course, Tables 1 and 2 clearly demonstrate the
differences in amino acids and nucleotides of the
25 flagellin proteins and genes of *B. lonestari* sp. nov. and
B. burgdorferi, the causative agent of Lyme disease in
North America (Barbour and Fish, 1993) and the most
relevant organism to distinguish *B. lonestari* sp. nov.
from in a diagnostic test.

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Exemplary species-specific combinations of
nucleotides where the nucleotide itself is not species-
specific are found by comparing the nucleotides of Table
2 and finding a combination of B1 nucleotides that is not
35 represented in any of the other species listed in the
context of the sequence of SEQ ID NO: 1. Examples
include: nucleotide NT # 30 and 225, 42 and 225, 177 and

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297, 303 and 312, 350 and 355, 375 and 419, 432 and 435, 458 and 475, and 501 and 516 of SEQ ID NO:1, for example.

With these examples, one skilled in the art would, upon further examination of Table 2, find further species-specific combinations of nucleotides in the context of
5 SEQ ID NO: 1 for identification of *B. lonestari* sp. nov.

An embodiment of the present invention is a purified nucleic acid molecule comprising a nucleotide sequence of
10 about 12 to about 709 nucleotides that encodes a *B. lonestari* sp. nov. flagellin peptide having at least one *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids from Table 1, or a complement thereof. In a preferred embodiment, the
15 nucleotide sequence has the sequence of SEQ ID NO:1, 4 or 26. An even more preferred embodiment is a purified nucleic acid molecule having a nucleotide sequence encoding a protein having an amino acid sequence of SEQ ID NO: 2, a partial sequence of the *B. lonestari* sp. nov.
20 flagellin protein.

Further embodiments include a recombinant molecule comprising the nucleic acid molecule described above, a host cell comprising the recombinant molecule and the
25 recombinant molecule is preferably an expression vector. The nucleic acid segments of the present invention, regardless of the length of the coding sequence itself, may be combined with other DNA sequences, such as promoters, polyadenylation signals, additional
30 restriction enzyme sites, multiple cloning sites, other coding segments, and the like, such that their overall length may vary considerably. It is contemplated that a nucleic acid fragment of almost any length may be employed, with the total length preferably being limited
35 by the ease of preparation and use in the intended recombinant DNA protocol.

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The at least one *B. lonestari* sp. nov. specific amino acid may be at position 24, 65, 67, 90, 91, 92, 99, 103, 119, 126, 127, 136, 140, 174, or 191 of SEQ ID NO:2 as shown in Table 1. The at least one *B. lonestari* sp. nov.-specific combination of amino acids is also obtained from Table 1 as described above.

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TABLE 1

Comparison of Amino Acids at Designated Positions of the
Flagellin Protein of Various *Borrelia* Species

Aa# ¹	B1 ²	Bb	Ba	Bh	Bc	Bz
24	<u>V</u> ^{3,6}	I	I	I	I	I
41	S	A	A	A	S	A
42	A	S	A	A	A	S
46	K	R	R	K	R	K
65	<u>T</u>	S	S	A	S	S
67	<u>A</u>	S	S	S	S	S
90 ⁴	<u>F</u>	Y	Y	Y	Y	Y
91	<u>S</u>	A	A	A	A	A
92	<u>T</u>	A	A	S	A	A
99	<u>G</u>	S	A	A	S	A
103	<u>V</u>	A	A	A	A	A
Δ104	- ⁵	Q	-	-	Q	Q
Δ105	-	AA	-	-	-	AA
108	A	V	A	V	A	V
112	A	V	A	G	A	A
117	V	A	V	V	A	A
119	<u>P</u>	Q	A	A	A	Q
Δ120	-	5 amino acids	6 amino acids	6 amino acids	6 amino acids	5 amino acids
122	A	S	A	A	A	T
126	<u>I</u>	V	V	V	V	V
127	<u>S</u>	N	N	N	N	N
130	I	V	I	I	V	V
135	A	T	A	A	A	T
136	<u>I</u>	V	V	V	V	V
140	<u>A</u>	T	M	M	M	T
144	T	A	A	A	T	A
147	D	N	D	G	D	N

TABLE 1 (cont.)

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Aa# ¹	B1 ²	Bb	Ba	Bh	Bc	Bz
152	V	I	V	V	I	I
153	T	S	S	S	T	S
169	V	I	I	I	V	I
171	A	N	D	D	A	N
174	<u>D</u>	E	E	E	E	E
191	<u>I</u>	T	T	T	T	T
196	I	V	I	V	I	V
199	S	A	S	S	S	A

¹Aa#: amino acid number from SEQ ID NO:2.

²Abbreviations: B1, *Borrelia lonestari* sp. nov.; Bb, *B. burgdorferi*; Ba, *B. anserina*; Bh, *B. hermsii*; Bc, *B. crocidurae*; Bz, *B. afzelii*.

³Underline: Amino acid positions that are species-specific to B1.

⁴Italics indicate positions or a range of amino acid positions where a peptide would be species-specific for B1.

⁵-, deletion.

⁶Amino acids have three and one letter designations as follows, either designation may be used herein: Alanine = Ala (A); Arginine = Arg (R); Aspartate = Asp (D); Asparagine = Asn (N); Cysteine = Cys (C); Glutamate = Glu (E); Glutamine = Gln (Q); Glycine = Gly (G); Histidine = His (H); Isoleucine = Ile (I); Leucine = Leu (L); Lysine = Lys (K); Methionine = Met (M); Phenylalanine = Phe (F); Proline = Pro (P); Serine = Ser (S); Threonine = Thr (T); Tryptophan = Trp (W); Tyrosine = Tyr (Y); Valine = Val (V).

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The at least one *B. lonestari* sp. nov.-specific amino acid or combination of amino acids can be considered an allotype of this species. Preferably, the length of the oligonucleotide is from about 12 to about 641 nucleotides; or in other embodiments, from about 12 to about 330 nucleotides; or 12 to about 300; or 12 to about 150; or 12 to about 99; and in still other embodiments, from about 15 to about 30 nucleotides. In other embodiments, the nucleotide sequence encodes amino acid(s) at and flanking position 24, 65, 67, 90, 91, 92, 99, 103, 119, 126, 127, 136, 140, 174, or 191 of SEQ ID NO:2. Preferably, the sequence encodes amino acids at and flanking positions 90-92, 103-108, 119-127, 136-144, or 171-174 of SEQ ID NO:2. In another embodiment, the sequence encodes a species-specific combination of amino acids of Table 1 having flanking amino acids from SEQ ID NO:2. The oligonucleotide may be defined further as including a detectable label. Some oligonucleotides may be defined further as comprising the sequence GGTGTTCAAGCG, SEQ ID NO:7 or GTTCAACCAGCT, SEQ ID NO:8. These sequences are unique to *B. lonestari* sp. nov. due to the presence of a number of nucleotides at particular positions around 310 and 358 of the flagellin gene of other *Borrelia* species. These species-specific oligonucleotides are useful as hybridization probes for the detection of *B. lonestari* sp. nov. in a diagnostic assay.

A further embodiment of the invention is a purified nucleic acid molecule comprising a nucleotide sequence represented in SEQ ID NO:1 or 3 having at least one *B. lonestari* sp. nov.-specific nucleotide or species-specific combination of nucleotides from Table 2 or 3, or a complement thereof. Another embodiment is a purified flagellin gene of *B. lonestari* sp. nov. A further embodiment of the present invention is a nucleic acid segment that comprises at least a 10-14 nucleotide long

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stretch that corresponds to, or is complementary to, the nucleic acid sequence of SEQ ID NO:1 and includes an allele as described in Table 2. In a more preferred embodiment, the nucleic acid is further defined as

5 comprising at least about a 20 nucleotide long stretch, about 30 nucleotide long stretch, about 50 nucleotide long stretch, about 100 nucleotide long stretch, about 200 nucleotide long stretch, about 400 nucleotide long stretch, about 600 nucleotide long stretch, or a full

10 length sequence that corresponds to, or is complementary to, the nucleic acid sequence of SEQ ID NO:1 and includes an allele as described in Table 2.

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TABLE 2

Comparison of Nucleotides at Designated Positions of
the Flagellin Gene as Listed in SEQ ID NO:1
for Various *Borrelia* Species

Nt# ¹	B1 ²	Bb	Ba	Bh	Bc	Bz
30	T	A	T	T	T	A
42	T	A	T	T	T	A
45	A	G	G	G	A	G
57	T	C	T	T	T	C
62	T	T	T	C	C	T
66	C	T	C	C	T	T
70 ³	<u>G</u> ⁴	A	A	A	A	A
81	G	A	A	G	A	G
90	C	T	T	C	T	T
96	<u>G</u>	A	A	A	T	A
102	T	C	T	T	T	C
108	A	A	G	G	A	G
117	A	A	G	G	A	A
120	A	T	A	A	A	T
121	T	G	G	G	T	G
124	G	T	G	G	G	T
137	A	G	G	A	G	A
141	<u>T</u>	A	A	A	A	A
177	T	C	T	C	T	C
192	A	T	A	A	A	T
193	<u>A</u>	T	T	G	T	T
199	<u>G</u>	T	T	T	T	T
201	A	T	A	A	A	T
210	A	T	A	A	A	T
219	G	A	A	G	A	A
225	T	T	A	A	A	T
228	<u>G</u>	T	T	T	T	T
231	<u>A</u>	T	G	G	T	G

TABLE 2 (cont.)

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Nt# ¹	B1 ²	Bb	Ba	Bh	Bc	Bz
234	T	A	T	C	T	A
261	T	A	T	T	T	A
269	<u>T</u>	A	A	A	A	A
270	<u>C</u>	T	T	T	T	T
271	<u>T</u>	G	G	G	G	G
273	<u>A</u>	G	G	T	G	G
295	G	T	G	G	T	G
297	T	T	A	A	A	T
300	<u>A</u>	T	T	T	T	T
303	A	G	A	A	G	G
306	T	A	T	C	T	A
308	<u>T</u>	C	C	C	C	C
Δ310	-	CAA	-	-	CAA	CAA
Δ311	-	ACTGCT	-	-	-	GCTGCT
312	A	G	G	G	A	G
315	<u>G</u>	T	T	T	A	T
318	T	A	T	T	T	A
321	A	G	A	A	A	T
323	C	T	C	T	C	T
333	T	T	A	A	T	T
336	A	T	A	A	A	T
339	A	A	A	G	G	A
342	G	G	A	A	A	A
350	T	C	T	G	C	C
355	C	C	G	G	G	C
356	C	A	C	C	C	A
Δ358	-	N ₁₅	N ₁₈ ⁵	N ₁₈	N ₁₈	N ₁₅
360	T	A	T	T	T	A
363	A	T	A	A	A	T
375	G	A	G	A	A	A
376	<u>A</u>	G	G	G	G	G
380	<u>G</u>	A	A	A	A	A

TABLE 2 (cont.)

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Nt# ¹	B1 ²	Bb	Ba	Bh	Bc	Bz
387	A	T	A	A	A	T
388	A	G	A	A	G	G
402	T	T	T	C	T	T
403	G	A	G	G	G	A
405	T	A	T	T	T	A
406	<u>A</u>	G	G	G	G	G
418	<u>G</u>	A	A	A	A	A
419	C	C	T	T	T	C
420	A	A	G	G	A	A
423	<u>G</u>	A	A	A	A	A
427	A	G	G	G	A	G
429	A	T	A	A	A	T
432	G	A	G	G	A	A
435	T	T	A	A	G	A
439	G	A	G	G	A	A
454	G	A	G	G	C	A
458	C	G	G	G	C	G
475	C	T	C	C	T	T
477	T	A	T	T	C	A
492	T	T	T	C	A	T
501	G	A	A	G	G	A
505	<u>G</u>	A	A	A	A	A
510	<u>A</u>	G	G	G	G	G
512	C	A	A	A	C	A
516	C	T	C	T	A	C
519	A	T	A	A	G	T
522	T	G	A	A	T	G
537	C	T	C	C	T	T
538	T	C	T	T	T	C
546	<u>G</u>	A	A	A	T	A
561	T	A	T	T	A	A
570	A	T	A	A	C	T

TABLE 2 (cont.)

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Nt# ¹	B1 ²	Bb	Ba	Bh	Bc	Bz
572	<u>T</u>	C	C	C	A	C
585	A	G	A	A	A	G
586	A	G	A	G	T	G
595	T	G	T	T	T	G
597	T	A	T	A	T	T
603	<u>C</u>	T	T	T	A	T
606	C	T	C	C	C	T
615	G	A	A	G	G	A
633	T	A	T	T	T	A

¹Nt#: nucleotide number from SEQ ID NO:1

²Abbreviations: B1, *Borrelia lonestari* sp. nov.; Bb, *B. burgdorferi*; Ba, *B. anserina*; Bh, *B. hermsii*; Bc, *B. crocidurae*; Bz, *B. afzelii*.

³Italicized nucleotide positions indicate a location or range of locations where an oligonucleotide would be species-specific for B1.

⁴Nucleotide positions at which the nucleotide for B1 is unique and, therefore, species-specific, are underlined.

⁵N_{15, 18} = a 15 or 18 nucleotide insert is present in these species compared to *B. lonestari* sp. nov., therefore, the sequence of nucleotides at this region of *B. lonestari* is species-specific.

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TABLE 3

B. lonestari sp. nov.-Specific 16s rRNA Gene Nucleotides¹

Nucleotide #'s of SEQ ID NO:3 that provide novel combinations	Nucleotide(s) in 16s rRNA gene that provide novel combinations
135, 146, 217	A, T, A
146, 217, 224	T, A, G
217, 224, 267	A, G, T
224, 267, 435	G, T, G
267, 435	T, G
435, 437, 522	G, T, C
437, 522	T, C
437, 522, 554	T, C, T
522, 554	C, T
522, 554, 564	C, T, T
554, 564	T, T
554, 564, 963	T, T, A

¹From Table 6 and comparison of SEQ ID NO:3 with sequences presented in sequence data base such as GenBank having accession numbers corresponding to those of footnote of Table 5.

The present invention also encompasses DNA segments which are complementary, or essentially complementary, to the sequence set forth in SEQ ID NO:1, 3, 4, 26 or other of the segments described herein. Nucleic acid sequences which are "complementary" are those which are capable of base-pairing according to the standard Watson-Crick complementarity rules. As used herein, the term "complementary sequences" means nucleic acid sequences which are substantially complementary, as may be assessed by the same nucleotide comparison set forth above, or as defined as being capable of hybridizing to the nucleic acid segment of SEQ ID NO:1, 3, 4 or 26 under relatively

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stringent conditions such as those described herein. The *B. lonestari* sp. nov. nucleotides set forth in Tables 2 and 3, however, are considered relatively invariant since they are species-specific or a combination of the nucleotides is species-specific.

A purified nucleic acid molecule comprising a nucleotide sequence encoding a *B. lonestari* sp. nov. 16s ribosomal RNA is a further embodiment of the present invention. Preferably, the nucleotide sequence has a sequence comprising SEQ ID NO:3. The nucleic acid may be defined further as a recombinant molecule.

A preferred embodiment of the present invention is a purified flagellin protein of *B. lonestari* sp. nov. The protein may be defined further as an amino acid sequence comprising SEQ ID NO:2. The term "the amino acid sequence of SEQ ID NO:2" means that the sequence substantially corresponds to a portion of SEQ ID NO:2 and has relatively few amino acids which are not identical to, or a biologically functional equivalent of, the amino acids of SEQ ID NO:2. The term "biologically functional equivalent" is well understood in the art and is further defined in detail herein as having the amino acids of SEQ ID NO:2 listed in Table 1, these amino acids being relatively invariant in their function as species-specific epitopes or combination of epitopes of *B. lonestari* sp. nov. The flagellin protein or portions thereof having species-specific epitopes or a combination of epitopes is useful in an immunoassay for the detection of *B. lonestari* sp. nov.

A purified peptide having an amino acid sequence comprising about 6 to about 213 amino acids of SEQ ID NO:2 that includes at least one *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids from Table 1 is a further embodiment of the

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present invention. Preferably, the peptide has from about 6 to about 212 amino acids; more preferably, from about 6 to about 150 amino acids; and in other embodiments, from about 6 to about 50 amino acids. The above-described peptide preferably includes *B. lonestari* sp. nov. specific amino acid(s) at and flanking position 24, 65, 67, 90, 91, 92, 99, 103, 119, 126, 127, 136, 140, 174, or 191 of SEQ ID NO:2. Preferably, the peptide includes amino acid(s) at and flanking positions 90-92, 103-108, 119-127, 136-144, or 171-174 of SEQ ID NO:2. In another embodiment, the peptide includes a species-specific combination of amino acids of Table 1 having flanking amino acids from SEQ ID NO:2. In some embodiments, the peptide may include a detectable label. Preferred peptides comprise the sequence Gly Val Gln Ala, SEQ ID NO:5 or the sequence Val Gln Pro. These sequences are unique to *B. lonestari* sp. nov. due to the presence of a number of nucleotides at particular positions of the flagellin gene of other *Borrelia* species.

These species-specific peptides are useful as epitopes for the detection of antibodies having specificity for a species-specific flagellin protein, for the detection of T cells or B cells having similar specificity, or as antigens in an immunoassay for the detection of *B. lonestari* sp. nov. or for the generation of antibodies to be used in an immunoassay. Purified antibodies that bind to *B. lonestari* sp. nov.-specific flagellin proteins or peptides are also provided.

A fusion protein or peptide comprising a segment of SEQ ID NO:2 having at least one *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids of Table 1 is also an aspect of the present invention. The fusion protein preferably comprises SEQ ID NO:26, however, one skilled in the art, in light of the present disclosure, would be able to construct a

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number of different fusion proteins from a variety of vectors and the *B. lonestari* sp. nov. DNA sequences provided herein. It will also be understood that amino acid and nucleic acid sequences may include additional residues, such as additional N- or C-terminal amino acids, and yet still be essentially as set forth in one of the sequences disclosed herein, so long as the sequence meets the criteria set forth above. Segments of the flagellin gene may be cloned next to N- and/or C-terminal sequences of genes for other proteins, such as, β -galactosidase or maltose binding protein. A signal peptide that may allow better expression may be optionally included in the fusion protein. It is not necessary that the flagellin protein be transported, however, the signal peptide may help to prevent protease digestion.

A preferred embodiment of the present invention is a method of detecting *B. lonestari* sp. nov. in a sample, e.g., from a subject. The method comprises contacting a sample suspected of containing *B. lonestari* sp. nov. nucleic acids with an isolated *B. lonestari* sp. nov.-specific nucleic acid segment, or a complement thereof, under conditions effective to allow nucleic acid hybridization, and detecting the hybridized nucleic acids thus formed.

An exemplary method comprises the step of contacting a nucleic acid sample from the subject with an oligonucleotide comprising a nucleotide sequence of about 12 to about 30 nucleotides from SEQ ID NO:1 that includes at least one *B. lonestari* sp. nov.-specific nucleotide or species-specific combination of nucleotides from Table 2 or 3, or a complement thereof, under conditions allowing hybridization to form a duplex, wherein duplex formation indicates the presence of *B. lonestari* sp. nov. Preferably, the nucleotide sequence comprises the

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sequence GGTGTTCAAGCG, SEQ ID NO:7 or GTTCAACCAGCT, SEQ ID NO:8. The oligonucleotide may comprise a detectable label and the complex may then be detected by reference to the label.

5

PCRTM methods may comprise the steps of:

- 10 (a) contacting the sample nucleic acids with a pair of nucleic acid primers that hybridize to specific sequences from a *B. lonestari* sp. nov nucleic acid sequence, the primers capable of amplifying a *B. lonestari* sp. nov-specific nucleic acid segment when used in conjunction with a polymerase chain reaction;
- 15 (b) conducting a polymerase chain reaction to create *B. lonestari* sp. nov-specific amplification products; and
- 20 (c) detecting the amplification products thus formed.

PCRTM methods may also comprise the steps of:

- 25 (a) contacting the sample nucleic acids with a pair of nucleic acid primers that hybridize to sequences from *B. lonestari* sp. nov nucleic acids, the primers capable of amplifying *B. lonestari* sp. nov nucleic acids when used in conjunction with a polymerase chain reaction;
- 30 (b) conducting a polymerase chain reaction to create *B. lonestari* sp. nov amplification products; and

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(c) sequencing the amplification products thus formed to identify the presence of *B. lonestari* sp. nov.-specific amplified sequences.

5 An exemplary method of detecting *B. lonestari* sp. nov. comprises the steps of amplifying a segment of DNA from the subject using a set of PCRTM primers, wherein the segment of DNA includes at least one *B. lonestari* sp. nov.-specific nucleotide or species-specific combination
10 of nucleotides from Table 2 or 3, and determining the nucleotide sequence of the segment. When the nucleotide sequence of the segment is found in SEQ ID NO:1 or 3, or a complement thereof, then *B. lonestari* sp. nov. is detected. The PCRTM primers may be designed to be
15 complementary to a region of SEQ ID NO: 1 or 3 or to sequences 5' and 3' to any segment to be amplified, and the primers may be complementary to a sequence outside of the herein defined sequences, i.e., in flanking vector or naturally occurring sequences, for example. It is
20 contemplated that regions of as few as 20 or 50 bases may be amplified, or as long as 500 or 1000 bases. One of skill in this art would also understand, in light of the present disclosure, that other means of amplification of DNA or RNA segments would also be applicable to the
25 techniques defined herein.

The present invention also provides a method of detecting *B. lonestari* sp. nov. in a sample, e.g., from a subject, comprising the step of analyzing a DNA sample
30 from the subject for a restriction fragment length polymorphism that is unique to *B. lonestari* sp. nov. A preferred restriction fragment length polymorphism is from an AluI restriction enzyme digest.

35 Another embodiment of the present invention is a method of detecting a previously elicited immune response to *B. lonestari* sp. nov. in a subject. This method may

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be an antibody test or a cell mediated immunity test. The method comprises detecting an anti-*B. lonestari* sp. nov. antibody or T cell in a sample by contacting a sample suspected of containing said antibody or T cell with a *B. lonestari* sp. nov.-specific flagellin protein, peptide or fusion protein, under conditions effective to allow the formation of antibody-protein or T cell-protein immune complexes, and detecting the immune complexes so formed.

10

A preferred method comprises the step of contacting a sample from the subject with an epitope having at least a partial amino acid sequence of SEQ ID NO:2 that includes at least one *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids from Table 1, is also an embodiment of the present invention. Contacting of the sample would be under conditions allowing epitope-antibody or epitope-T cell binding to occur to form a complex, and complex formation indicates the presence of a previously elicited immune response to *B. lonestari* sp. nov. Preferably, the epitope is bound to a detectable label, and a preferred epitope is a flagellin fusion protein. The present inventors also envision the detection of B cells secreting antibody having epitope specificity as defined herein.

General immunodetection methods involve contacting a sample suspected of containing *B. lonestari* sp. nov. with an antibody that binds to a *B. lonestari* sp. nov.-specific flagellin protein or peptide, under conditions effective to allow the formation of immune complexes, and detecting the immune complexes so formed.

A preferred method of detecting *B. lonestari* sp. nov. in a subject comprising the step of contacting a sample from the subject with an antibody having binding

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specificity for an epitope having an amino acid sequence from SEQ ID NO:2 that includes at least one *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids from Table 1 is also an
5 embodiment of the present invention. The contacting is under conditions allowing epitope-antibody binding to occur to form a complex and complex formation indicates the presence of *B. lonestari* sp. nov. Preferably, the
10 epitope has a number of amino acids less than that of SEQ ID NO:2. In these immunoassay procedures, a further step of contacting the complex with a detectably labeled antibody having binding specificity for the complex may be included.

15 Most preferably, the subject of these detection methods is a human suspected of being infected with *B. lonestari* sp. nov., although suspected animal reservoirs are also preferred. Any animal that may have been bitten by a tick and that may carry this new
20 spirochete may be tested, including domestic animals such as dogs, cats, cattle, or turkeys, for example.

A test kit for the detection of *B. lonestari* sp. nov. in a biological sample is also an aspect of the
25 present invention. Nucleic acid detection kits will generally comprise, in suitable container means, an isolated *B. lonestari* sp. nov.-specific nucleic acid segment and a detection reagent.

30 Preferably, kits may comprise in packaged combination; a carrier means adapted to receive a plurality of container means in close confinement therewith; a first container means including an
35 oligonucleotide comprising a nucleotide sequence that includes at least one *B. lonestari* sp. nov.-specific nucleotide or species-specific combination of nucleotides from Table 2 or 3, or a complement thereof; and at least

- 25 -

one microtiter plate. The oligonucleotide may encode all of SEQ ID NO:2 or a portion thereof.

5 Immunodetection kits will generally comprise, in suitable container means, an isolated *B. lonestari* sp. nov.-specific flagellin protein or peptide, or a first antibody that binds to a *B. lonestari* sp. nov.-specific flagellin protein or peptide, and an immunodetection reagent.

10

The kits may preferably have a first container means including a first antibody having binding specificity for an epitope, the epitope having a partial or complete amino acid sequence of SEQ ID NO:2 and including at least 15 one *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids from Table 1; and a second container means including a quantity of a detectably labelled antibody having binding specificity for the first antibody.

20

A further alternative is where a first container means includes a peptide epitope, the epitope being a partial or complete amino acid sequence of SEQ ID NO:2 and including at least one *B. lonestari* sp. nov.-specific 25 amino acid or species-specific combination of amino acids from Table 1; and a second container means including a quantity of a detectably labelled antibody having binding specificity for immunoglobulin of the biological sample.

30 In these test kits, the detectably labelled antibody may be an enzyme-linked antibody, a fluorescently tagged antibody, or a radiolabeled antibody. Preferably, the detectably labelled antibody is an enzyme-linked antibody, and the kit further includes a third container 35 means including a quantity of a substrate for the enzyme sufficient to produce a visually detectable product.

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A diagnostic kit for determining the presence of *B. lonestari* sp. nov., in accordance with the present invention, may comprise any one or more of the following components:

5

1. Unique components in accordance with the present invention:

10

a. An oligonucleotide complementary to a portion of the flagellin gene or the 16s rRNA gene at a region having a species-specific nucleotide or species-specific combination of nucleotides.

15

20

b. Oligonucleotide primers for PCRTM designed to amplify a sequence of SEQ ID NO:1 or 3 where a first primer has a sequence 5' to a region of SEQ ID NO:1 or 3 having a species-specific nucleotide or species-specific combination of nucleotides and a second primer has a sequence 3' to the region. Primers may be designed to hybridize outside of the sequences depicted by SEQ ID NO: 1 or 3, since they may be complementary to vector sequences or naturally occurring flanking sequences, for example.

25

30

c. A double stranded internal fragment of SEQ ID NO:1 or 3 provided for cloning and DNA sequencing to confirm the identity of a sequenced test fragment.

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d. DNA comprising the nucleic acid sequence of SEQ ID NO:1, 3 or 4 as a positive control template DNA for hybridization, sequencing, or RFLP analyses. This DNA may comprise plasmid DNA from clones described in Examples 2 and 3.

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- e. Antibody having binding specificity for a *B. lonestari* flagellin species-specific epitope or species-specific combination of epitopes.
- 5 f. A peptide having an amino acid sequence that includes a species-specific amino acid or species-specific combination of amino acids of Table 1.
- 10 2. Commercially available reagents:
 - a. Components of a PCRTM reaction protocol.
 - b. Components of a dideoxy-based sequencing
15 protocol.
 - c. Components of an ELISA protocol.

20 The following listing provides an identification of those sequences provided with sequence identifiers.

Identity of Sequences having Sequence Identifiers

SEQ ID NO:	Identity of Sequence
1	A composite sequence representing a partial nucleotide sequence of flagellin gene of new species
2	Partial amino acid sequence of flagellin protein of new species
3	Partial nucleotide sequence of 16s rRNA of new species
4	Partial nucleotide sequence of flagellin gene, initial fragment cloned and obtained by PCR TM amplification, shorter than #1
5	Species-specific epitope of flagellin at about amino acid 103
6	Species-specific oligonucleotide of flagellin at about nucleotide 121
7	Species-specific oligonucleotide of flagellin at about nucleotide 304
8	Species-specific oligonucleotide of flagellin at about nucleotide 349
9	FlaLS primer for PCR TM
10	FlaRS primer for PCR TM
11	FlaLL primer for PCR TM
12	FlaRL primer for PCR TM
13	16RnaL primer for PCR TM
14	16RnaR primer for PCR TM
15-25	Fragments of flagellin from various spirochetes for alignment purposes
26	Partial sequence of plasmid encoding fusion protein
27	N-terminal addition to flagellin protein in fusion construct after cleavage by protease
28	Partial nucleotide sequence of flagellin gene of clone 70 of a Texas tick of the new species; ATCC #69818, American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland 20852

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It will be understood that this invention is not limited to the exact nucleic acid and amino acid sequences described herein except for those species-specific nucleotides and amino acids and species-specific combinations of nucleotides and amino acids of Tables 1, 2 and 3. Therefore, DNA segments prepared in accordance with the present invention may also encode biologically functional equivalent proteins or peptides which have variant amino acid sequences. Such sequences may arise as a consequence of codon redundancy and functional equivalency which are known to occur naturally within nucleic acid sequences and the proteins thus encoded. Alternatively, functionally equivalent proteins or peptides may be created via the application of recombinant DNA technology, in which changes in the protein structure may be engineered, based on considerations of the properties of the amino acids being exchanged.

The process of selecting and preparing a nucleic acid segment which includes a sequence from within SEQ ID NO:1 or 3 may alternatively be described as preparing a nucleic acid fragment. Of course, fragments may also be obtained by other techniques such as, e.g., by mechanical shearing or by restriction enzyme digestion. Small nucleic acid segments or fragments may be readily prepared by, for example, directly synthesizing the fragment by chemical means, as is commonly practiced using an automated oligonucleotide synthesizer. Also, fragments may be obtained by application of nucleic acid reproduction technology, such as the PCRTM technology of U.S. Patent 4,603,102 (incorporated herein by reference), by introducing selected sequences into recombinant vectors for recombinant production, and by other recombinant DNA techniques generally known to those of skill in the art of molecular biology.

- 30 -

In terms of uses, the present invention specifically provides: the use of a DNA segment comprising an isolated *B. lonestari* sp. nov.-specific gene in the preparation of a recombinant *B. lonestari* sp. nov-specific biological component; the use of a DNA segment comprising an isolated *B. lonestari* sp. nov.-specific gene in the preparation of a diagnostic formulation for use in identifying *B. lonestari* sp. nov, for diagnosing a Lyme disease-like infection or for differentiating between Lyme disease and a Lyme disease-like condition; the use of a DNA segment comprising an isolated *B. lonestari* sp. nov.-specific gene in the preparation of a medicament for use in preventing or treating a *B. lonestari* sp. nov infection or a Lyme disease-like condition.

Also, the use of a *B. lonestari* sp. nov.-specific gene nucleic acid probe or primer in the preparation of a diagnostic formulation for use in identifying *B. lonestari* sp. nov, for diagnosing a Lyme disease-like infection or for differentiating between Lyme disease and a Lyme disease-like condition; and the use of a pair of nucleic acid primers from spatially distant regions of a *B. lonestari* sp. nov.-specific gene in the preparation of a diagnostic formulation for use in amplifying and identifying *B. lonestari* sp. nov.-specific nucleic acids, for diagnosing a Lyme disease-like infection or for differentiating between Lyme disease and a Lyme disease-like condition.

Further, the use of a purified *B. lonestari* sp. nov.-specific flagellin protein or peptide in the preparation of an antibody that binds to a *B. lonestari* sp. nov.-specific flagellin protein or peptide; the use of a purified *B. lonestari* sp. nov.-specific flagellin protein or peptide in the preparation of a diagnostic formulation for use in identifying *B. lonestari* sp. nov, for diagnosing a Lyme disease-like infection or for

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differentiating between Lyme disease and a Lyme disease-like condition; the use of a purified *B. lonestari* sp. nov.-specific flagellin protein or peptide in the preparation of a medicament for use in preventing or
5 treating a *B. lonestari* sp. nov infection or a Lyme disease-like condition.

Yet further, the use of a purified antibody that binds to a *B. lonestari* sp. nov.-specific flagellin
10 protein or peptide in the preparation of a diagnostic formulation for use in identifying *B. lonestari* sp. nov, for diagnosing a Lyme disease-like infection or for differentiating between Lyme disease and a Lyme disease-like condition; and the use of a purified antibody that
15 binds to a *B. lonestari* sp. nov.-specific flagellin protein or peptide in the preparation of a medicament for use in preventing or treating a *B. lonestari* sp. nov infection or a Lyme disease-like condition.

20 Also, the use of a purified *B. lonestari* sp. nov.-specific rRNA in the preparation of a diagnostic formulation for use in identifying *B. lonestari* sp. nov, for diagnosing a Lyme disease-like infection or for differentiating between Lyme disease and a Lyme disease-like condition.
25

BRIEF DESCRIPTION OF THE DRAWING

30 The following drawing forms part of the present specification and is included to further demonstrate certain aspects of the present invention. The invention may be better understood by reference to this drawing in combination with the detailed description of specific
35 embodiments presented herein.

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FIG. 1 shows a distance matrix phylogenetic tree of *Borrelia* spp. with *Treponema pallidum* as the outgroup. 16S rRNA sequences corresponding to base positions 36 through 1371 of *B. burgdorferi* rRNA gene (accession numbers U03396 and X57404) were aligned by the PileUp algorithm (Genetics Computer Group, Inc). Other sequences were *B. hermsii* (M60968 and L10136), *B. anserina* (M72397 and M64312), *B. miyamotoe* sp. nov. (D45192), the "Florida canine borrelia" (L37837), and *T. pallidum* (M88726). Aligned sequences were analyzed with the PHYLIP program package, version 3.5 (Felsenstein, 1989, 1993). Distance matrices were calculated with the Jukes-Cantor option of the DNADIST program. Multiple data sets were generated with SEQBOOT, unrooted trees were constructed using the NEIGHBOR program with the Neighbor-Joining option, and a consensus tree was generated with CONSENSE. Circles numbers indicate the number of times out of 100 that a particular node was supported by bootstrap analysis. Approximate evolutionary distances are measured along line segments; the bar represents a distance by Jukes-Cantor criteria of 0.005. The calculated distances of the *Amblyomma* borrelia from *B. hermsii*, *B. burgdorferi*, and *T. pallidum* were 0.022, 0.041, and 0.233, respectively. Tree topology was also examined by subjecting the 100 bootstrapped datum sets to parsimony analysis with the DNAPARS algorithm. The consensus treefile (New Hampshire Standard format) from the parsimony analysis was: (*Amblyomma* borrelia: 100, *B. miyamotoe*: 100): 94, *B. hermsii*: 100): 34, Florida canine borrelia: 100): 25, *B. anserina* 100): 81, *B. burgdorferi*: 100): 100, *T. pallidum*: 100).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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The newly recognized tick-borne disease in Texas, Missouri, and states in the south central and

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southeastern United States is similar to Lyme disease in many respects but cannot be distinguished from Lyme disease by visual inspection of the rash, for example. Another *Borrelia* disease that is difficult to distinguish from Lyme disease, using the standard laboratory test for Lyme disease, is relapsing fever which is associated with bites from *Ornithodoros* spp. ticks.

The present invention provides diagnostic tests based on species-specific regions or species-specific combination of regions of the flagellin protein, the flagellin gene, or the 16s rRNA of the new spirochete, named by the present inventors as *Borrelia lonestari* sp. nov. The flagellin protein is sufficiently different from other *Borrelia* spp. that a serodiagnostic assay based on flagellin antigen (recombinant, synthetic, or native) is both sensitive and specific for putative infections. The DNA sequences of both the flagellin gene and the rRNA gene provide a means for PCRTM and other nucleic acid-based technologies to identify the organism from skin, body fluid, or cellular specimen of a person, animal, insect and the like, suspected of being infected. Animal reservoirs that are particularly suspect include deer and ground-feeding birds. The diagnostic tests provided herein provide clinical laboratory differentiation of the new tick-borne disease from the causative agents of Lyme disease and relapsing fever. The demonstration of *B. lonestari* sp. nov. in humans provides the basis for a diagnosis of infection by this new spirochete.

***B. lonestari* sp. nov.--Species-Specific Amino Acid(s) and Species-Specific Combinations of Amino Acid(s) from the Flagellin Protein**

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A preferred embodiment of the present invention is a purified composition comprising a polypeptide having an

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amino acid sequence in accordance with SEQ ID NO:2. The term "purified" as used herein, is intended to refer to a flagellin protein composition, wherein the flagellin protein is purified to any degree relative to its naturally-obtainable state, i.e., in this case, relative to its purity as part of a *Borrelia* cell extract. A preferred cell for the isolation of flagellin protein is a *B. lonestari* sp. nov. cell, however, this flagellin protein may also be isolated from the *A. americanum* tick, patient specimens, recombinant cells, tissues, and the like, as will be known to those of skill in the art, in light of the present disclosure. A purified flagellin protein composition therefore also refers to a polypeptide comprising the amino acid sequence of SEQ ID NO:2, free from the environment in which it may naturally occur. The flagellin protein may be purified by a procedure of Barbour et al. (1986), for example.

The present inventors have prepared and envision the preparation of various fusion proteins and peptides, e.g., where species-specific flagellin gene coding regions or species-specific combination of flagellin gene coding regions are aligned within the same expression unit with nucleotide sequences encoding other proteins or peptides having desired functions, such as for purification or immunodetection purposes (e.g., proteins which may be purified by affinity chromatography and enzyme label coding regions, respectively).

Table 1 provides a listing of those species-specific amino acids and species-specific combinations of amino acids of the partial sequence of the flagellin protein of *B. lonestari* sp. nov. provided as SEQ ID NO:2. These amino acids or species-specific combinations thereof represent variations in their respective positions compared to the corresponding available sequences of other *Borrelia* species.

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The species-specific amino acids or species-specific combination of amino acids of this new spirochete provide unique epitopes for assay for identification of the organism. Two types of immunoassay are contemplated: i) the first uses an epitope comprising a peptide having a sequence represented in SEQ ID NO:2 and containing a *B. lonestari* sp. nov.-specific amino acid(s) or species-specific combination of amino acids of Table 1 to assay for the presence of antibodies having specificity for that epitope in a clinical sample and, ii) the second type of immunoassay uses antibodies that have been raised to such an epitope to assay for the presence of the epitope in the clinical sample.

An epitope useful for immunoassay contains at least one of the *B. lonestari* sp. nov.-specific amino acids or species-specific combination of amino acids of Table 1 together with at least about 4, 5, or 6 amino acids that flank that amino acid(s) in the flagellin protein sequence designated SEQ ID NO:2. Where the uniqueness of the flagellin protein is due to a deletion of residues compared to other *Borrelia* species, then the epitope contains at least two, and preferably 3 or 4 amino acids from that region of SEQ ID NO:2 as cited in Table 1 and is flanked with further amino acids on both sides of the epitope from SEQ ID NO:2. Such peptide epitopes may be made synthetically, or may be isolated from natural sequences by enzyme digestion, for example, or may be produced by recombinant means, described more fully herein.

As used herein, "an epitope useful for immunoassay" refers to a peptide or protein antigen which includes a primary, secondary or tertiary structure similar to an epitope comprising a *B. lonestari* sp. nov.-specific amino acid(s) or species-specific combination of amino acids of Table 1 located within the flagellin protein of

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B. lonestari sp. nov. The level of similarity will generally be to such a degree that monoclonal or polyclonal antibodies directed against the *B. lonestari* sp. nov. flagellin protein will bind to, react with, or otherwise recognize, the peptide or protein antigen.

In general, the size of the polypeptide epitope is at least large enough to carry an identified *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids of Table 1. The smallest useful core sequence contemplated by the present disclosure would generally be on the order of about 6 amino acids in length. Thus, this size will generally correspond to the smallest peptide antigens prepared in accordance with the invention. It is proposed that short peptides that incorporate a species-specific amino acid or species-specific combination of amino acids of Table 1 will provide advantages in certain circumstances, for example, in the preparation of vaccines or in immunologic detection assays. Exemplary advantages of shorter peptides include the ease of preparation and purification, and the relatively low cost and improved reproducibility of production. However, the size of the epitope may be larger where desired, so long as it contains a peptide sequence of SEQ ID NO:2 having a *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids of Table 1. Longer peptide epitopes for use in accordance with the present invention will generally be on the order of 15 to 30 amino acids in length, and more preferably about 15 to about 50 amino acids in length.

Additionally or alternatively, an epitopic sequence of the present invention is one that elicits antibodies that react with *B. lonestari* sp. nov. flagellin protein of SEQ ID NO:2 and the antibodies do not cross-react with flagellin protein from other *Borrelia* species. Thus,

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epitope sequences of the present invention may be operationally defined in terms of their ability to compete with or perhaps displace the binding of the peptide of SEQ ID NO:2 with the corresponding flagellin-directed antisera.

Syntheses of epitopic peptides are readily achieved using conventional synthetic techniques such as the solid-phase method (e.g., through the use of commercially available peptide synthesizer such as an Applied Biosystems Model 430A Peptide Synthesizer). Peptide epitopes synthesized in this manner may then be aliquotted in predetermined amounts and stored in conventional manners, such as in aqueous solutions or, even more preferably, in a powder or lyophilized state pending use.

In general, due to the relative stability of peptides, they may be readily stored in aqueous solutions for fairly long periods of time if desired, e.g., up to six months or more, in virtually any aqueous solution without appreciable degradation or loss of antigenic activity. However, where extended aqueous storage is contemplated, it will generally be desirable to include agents including buffers such as Tris or phosphate buffer to maintain a pH of 7.0 to 7.5. Moreover, it may be desirable to include agents which will inhibit microbial growth, such as sodium azide or merthiolate. For extended storage in an aqueous state it will be desirable to store the solutions at 4°C, or more preferably, frozen. Of course, where the peptide(s) are stored in a lyophilized or powdered state, they may be stored virtually indefinitely, e.g., in metered aliquots that may be rehydrated with a predetermined amount of water (preferably distilled) or buffer prior to use.

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Peptides may be labeled with ^{125}I , ^{131}I , or other radiolabel as a means for detection, or may be labeled with a chromophore, such as, for example, biotin, HRP, or alkaline phosphatase, for detection.

5

Antibodies

In another aspect, the present invention contemplates an antibody that is immunoreactive with an epitope having a sequence of SEQ ID NO:2 containing a *B. lonestari* sp. nov.-specific amino acid(s) or species-specific combination of amino acids of Table 1. An antibody can be a polyclonal or a monoclonal antibody. In a preferred embodiment, an antibody is a monoclonal antibody. Means for preparing and characterizing antibodies are well known in the art (See, e.g., *Antibodies "A Laboratory Manual*, E. Howell and D. Lane, Cold Spring Harbor Laboratory, 1988).

Briefly, a polyclonal antibody is prepared by immunizing an animal with an immunogen comprising an epitope of the present invention and collecting antisera from that immunized animal. A wide range of animal species can be used for the production of antisera. Typically an animal used for production of anti-antisera is a rabbit, a mouse, a rat, a hamster, a guinea pig, or a goat. Because of the relatively large blood volume of goats and rabbits, a goat or rabbit is a preferred choice for production of polyclonal antibodies.

30

Antibodies, both polyclonal and monoclonal, specific for an epitope of the present invention may be prepared using conventional immunization techniques, as will be generally known to those of skill in the art. A composition comprising an epitope having a sequence represented in SEQ ID NO:2 and containing a *B. lonestari* sp. nov.-specific amino acid or species-specific

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combination of amino acids of Table 1 can be used to immunize one or more experimental animals, such as a rabbit or mouse, which will then proceed to produce specific antibodies against the peptide epitope.

- 5 Polyclonal antisera may be obtained, after allowing time for antibody generation, simply by bleeding the animal and preparing serum samples from the whole blood.

- 10 To obtain monoclonal antibodies, one would also initially immunize an experimental animal, preferably a mouse, with the above-described composition. One would then, after a period of time sufficient to allow antibody generation, obtain a population of spleen or lymph cells from the animal. The spleen or lymph cells can then be
15 fused with cell lines, such as human or mouse myeloma strains, to produce antibody-secreting hybridomas. These hybridomas may be isolated to obtain individual clones which can then be screened for production of antibody to the desired species-specific epitope or species-specific
20 combination of epitopes of *B. lonestari* sp. nov.

- Following immunization, spleen cells are removed and fused, using a standard fusion protocol (see, e.g., The Cold Spring Harbor Manual for Hybridoma Development,
25 incorporated herein by reference) with plasmacytoma cells to produce hybridomas secreting monoclonal antibodies against a species-specific epitope or species-specific combination of epitopes. Hybridomas which produce monoclonal antibodies to the species-specific epitope or
30 species-specific combination of epitopes are identified using standard techniques, such as ELISA and Western blot methods.

- Hybridoma clones can then be cultured in liquid
35 media and the culture supernatants purified to provide the *B. lonestari* sp. nov.-specific monoclonal antibodies. In general, for uses in accordance with the present

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invention, one will preferably desire to select those hybridomas that secrete antibodies having a high affinity for the species-specific epitopes or species-specific combination of epitopes of flagellin protein, and exhibit
5 minimal binding to other *Borrelia* species flagellin protein.

Monoclonal antibodies to the desired *B. lonestari* sp. nov.-specific flagellin epitopes or species-specific
10 combination of flagellin epitopes can be used in the diagnosis of infections caused by the *Amblyomma* tick and that are Lyme disease-like but test negative for Lyme disease.

15 It is proposed that the monoclonal antibodies of the present invention will find useful application in standard immunochemical procedures, such as ELISA and Western blot methods, as well as other procedures, such as immunohistology of tissues, that may utilize antibody
20 specific to the species-specific epitopes or species-specific combination of epitopes of the present invention. Additionally, species-specific monoclonal antibodies may be useful in immunoadsorbent protocols for purifying native or recombinant *B. lonestari* sp. nov.
25 flagellin protein or minor variants thereof.

Both poly- and monoclonal antibodies may be employed in antibody cloning protocols to obtain genes encoding *B. lonestari* sp. nov. flagellin or related proteins.
30 Species-specific anti-flagellin antibodies will also be useful in immunolocalization studies to analyze the distribution of flagellin protein during various cellular events, for example, to determine the cellular and membrane distribution during flagella assembly. A
35 particularly useful application of such antibodies is in purifying native or recombinant flagellin protein, for example, using an antibody affinity column. The

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operation of all such immunological techniques will be known to those of skill in the art in light of the present disclosure.

5 **Immunoassays**

10 The present invention envisions the use of immunoassays for the detection of *B. lonestari* sp. nov.-specific epitopes or species-specific combination of epitopes for the diagnosis of the presence of *B. lonestari* sp nov. Various immunoassay methods may be employed, such as, for example, Western blotting, ELISA, RIA, and the like, all of which are known to those of skill in the art.

15

15 Enzyme linked immunoabsorbent assays (ELISAs) may be used in conjunction with the invention. In an ELISA assay, proteins or peptides incorporating species-specific sequences or species-specific combination of sequences are immobilized onto a selected surface, preferably a surface exhibiting a protein affinity such as the wells of a polystyrene microtiter plate. After washing to remove incompletely adsorbed material, it is desirable to bind or coat the assay plate wells with a nonspecific protein that is known to be antigenically neutral with regard to the test antisera such as bovine serum albumin (BSA), casein or solutions of milk powder. This allows for blocking of nonspecific adsorption sites on the immobilizing surface and thus reduces the background caused by nonspecific binding of antisera onto the surface.

30 After binding of antigenic material to the well, coating with a non-reactive material to reduce background, and washing to remove unbound material, the immobilizing surface is contacted with the antisera or clinical or biological extract to be tested in a manner

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conductive to immune complex (antigen/antibody) formation. Such conditions preferably include diluting the antisera with diluents such as BSA, bovine gamma globulin (BGG) and phosphate buffered saline (PBS)/Tween. These added
5 agents also tend to assist in the reduction of nonspecific background. The layered antisera is then allowed to incubate for from 2 to 4 hours, at temperatures preferably on the order of 25° to 27°C. Following incubation, the antisera-contacted surface is
10 washed so as to remove non-immunocomplexed material. A preferred washing procedure includes washing with a solution such as PBS/Tween, or borate buffer.

Following formation of specific immunocomplexes
15 between the test sample and the bound antigen, and subsequent washing; the occurrence and even amount of immunocomplex formation may be determined by subjecting same to a second antibody having specificity for the first. To provide a detecting means, the second antibody
20 will preferably have an associated enzyme that will generate a color development upon incubating with an appropriate chromogenic substrate. Thus, for example, one will desire to contact and incubate the antisera-bound surface with a urease or peroxidase-conjugated
25 anti-appropriate-animal IgG for a period of time and under conditions which favor the development of immunocomplex formation (e.g., incubation for 2 hours at room temperature in a PBS-containing solution such as PBS-Tween).

30

After incubation with the second enzyme-tagged
antibody, and subsequent to washing to remove unbound
material, the amount of label is quantified by incubation
with a chromogenic substrate such as urea and bromocresol
35 purple or 2,2'-azino-di-(3-ethyl-benzthiazoline-6-sulfonic acid [ABTS] and H₂O₂, in the case of peroxidase as the enzyme label. Quantification is then achieved by

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measuring the degree of color generation, e.g., using a visible spectra spectrophotometer.

5 The antibody compositions of the present invention
find great use in immunoblot or Western blot analysis.
The antibodies may be used as high affinity primary
reagents for the identification of proteins immobilized
onto a solid support matrix, such as nitrocellulose,
polyacrylamide, nylon, or the like. In conjunction with
10 gel electrophoresis and immunoprecipitation, the
antibodies may be used as a single step reagent for use
in detecting species-specific epitopes of *B. lonestari*
sp. nov. Immunologically-based detection methods for use
in conjunction with Western blotting include
15 enzymatically-, radiolabel-, or fluorescently-tagged
secondary antibodies against the primary antibody moiety
are considered to be of particular use in this regard.

Other methods for detection of antigens and
20 antibodies well known in a clinical laboratory setting
are contemplated by the present invention, including:
immunodiffusion, electrophoresis and
immuno-electrophoresis, immunochemical and physicochemical
methods, binder-ligand assays, immunohistochemical
25 techniques (immunofluorescence), agglutination, IgG and
IgM capture assay test, competitive inhibition assays for
antibodies, or complement assays.

Immunodetection Kits

In still further embodiments, the present invention concerns immunodetection methods and associated kits. It is proposed that the *B. lonestari* sp. nov.-specific peptides or species-specific combination of peptides of the present invention may be employed to detect antibodies having reactivity therewith, or, alternatively, antibodies prepared in accordance with the present invention, may be employed to detect species-specific proteins or peptides or species-specific combinations thereof. In general, these methods will include first obtaining a sample suspected of containing such a protein, peptide or antibody, contacting the sample with an antibody or species-specific protein or peptide or species-specific combination of protein or peptide in accordance with the present invention, as the case may be, under conditions effective to allow the formation of an immunocomplex, and then detecting the presence of the immunocomplex.

In general, the detection of immunocomplex formation is quite well known in the art and may be achieved through the application of numerous approaches. For example, the present invention contemplates the application of ELISA, RIA, immunoblot, dot blot, indirect immunofluorescence techniques and the like. Generally, immunocomplex formation will be detected through the use of a label, such as a radiolabel or an enzyme tag (such as alkaline phosphatase, horseradish peroxidase, or the like). Of course, one may find additional advantages through the use of a secondary binding ligand such as a second antibody or a biotin/avidin ligand binding arrangement, as is known in the art.

For diagnostic purposes, it is proposed that virtually any sample suspected of comprising either the

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species-specific protein or peptide or antibody sought to be detected, as the case may be, may be employed.

Exemplary samples include the tick suspected of harboring the new *Borrelia* species, and clinical samples obtained from a patient such as blood or serum samples, a skin biopsy, cerebrospinal fluid, or urine samples. For antigen or DNA testing, a blood, CSF, or urine sample is preferred. A preferred sample for antibody tests is a blood or CSF sample. Furthermore, it is contemplated that such embodiments may have application to non-clinical samples, such as in the titering of antigen or antibody samples, in the selection of hybridomas, and the like.

In related embodiments, the present invention contemplates the preparation of kits that may be employed to detect the presence of species-specific proteins or peptides and/or antibodies in a sample. Generally speaking, kits in accordance with the present invention will include a suitable *B. lonestari* sp. nov.-specific protein or peptide, or species-specific combination thereof, or antibody directed against such a protein or peptide or species-specific combination thereof, together with an immunodetection reagent and a means for containing the antibody or antigen and reagent. The immunodetection reagent will typically comprise a label associated with the antibody or antigen, or associated with a secondary binding ligand. Exemplary ligands might include a secondary antibody directed against the first antibody or antigen or a biotin or avidin (or streptavidin) ligand having an associated label. Of course, as noted above, a number of exemplary labels are known in the art and all such labels may be employed in connection with the present invention.

The container means will generally include a vial into which the antibody, antigen or detection reagent may

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be placed, and preferably suitably aliquotted. The kits of the present invention will also typically include a means for containing the antibody, antigen, and reagent containers in close confinement for commercial sale.

- 5 Such containers may include injection or blow-molded plastic containers into which the desired vials are retained.

10 ***B. lonestari* sp. nov.-Specific Nucleotides and Species-Specific Combination of Nucleotides of the flagellin and 16s rRNA Genes.**

Further preferred embodiments of the present invention include a purified composition comprising a
15 nucleic acid having a nucleotide sequence in accordance with SEQ ID NOS:1, 3 or 4. The term "purified" as used herein, is intended to refer to a nucleic acid composition, in this case, a flagellin gene or segment thereof, or a rRNA gene or segment thereof, wherein the
20 nucleic acid is purified to any degree relative to its naturally-obtainable state, i.e., in this case, relative to its purity as part of a *Borrelia* cell extract. A preferred cell for the isolation of this nucleic acid is a *B. lonestari* sp. nov. cell, however, this nucleic acid
25 may also be isolated from the *A. americanum* tick, patient specimens, recombinant cells, tissues, and the like, as will be known to those of skill in the art, in light of the present disclosure. A purified nucleic acid composition therefore also refers to a nucleic acid
30 comprising the nucleotide sequence of SEQ ID NO:1, 3 or 4, free from the environment in which it may naturally occur.

The present inventors have prepared and envision the
35 preparation of various recombinant products comprising nucleotide segments representing whole or partial sequences of SEQ ID NO:1, 3 or 4, e.g., where species-

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specific flagellin gene coding regions or species-specific combination(s) of flagellin gene coding regions are aligned within the same expression unit with nucleotide sequences encoding other proteins or peptides to construct a fusion protein as herein described. Recombinant products include the vectors themselves, including, for example, plasmids, cosmids, phage, viruses, and the like. It will be understood that the present invention also encompasses sequences which are complementary to the sequences listed herein, along with biological functional equivalents thereof, including naturally occurring variants and genetically engineered mutants.

As used herein, the term "recombinant" is intended to refer to a vector or host cell into which a foreign piece of DNA, such as a gene encoding a *B. lonestari* sp. nov. nucleic acid, has been introduced. Therefore, engineered cells are distinguishable from naturally occurring cells that do not contain a recombinantly introduced gene. Engineered cells are thus cells having a gene or genes introduced through the hand of man. Recombinantly introduced genes will either be in the form of a copy of a genomic gene, or will include genes positioned adjacent to a promoter not naturally associated with the particular introduced gene.

Prokaryotic hosts may be used for expression of a *B. lonestari* sp. nov. protein. Some examples of prokaryotic hosts are: *E. coli*, such as for example, strain RR1, *E. coli* LE392, *E. coli* B, *E. coli* X 1776 (ATCC No. 31537, American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland 20852) as well as *E. coli* W3110 (F-, lambda-, prototrophic, ATCC No. 273325, American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland 20852); other enterobacteriaceae such as *Salmonella typhimurium* or *Serratia marcescens*;

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bacilli such as *Bacillus subtilis*; various *Pseudomonas* species, *Mycobacterium* species such as *bovis*, *Streptomyces* species, or *Clostridium* species may be used.

5 In general, plasmid vectors containing replicon and control sequences that are derived from species compatible with the host cell are used in connection with these hosts. The vector ordinarily carries a replication site, as well as marking sequences which are capable of
10 providing phenotypic selection in transformed cells. For example, *E. coli* is typically transformed using pBR322, a plasmid derived from an *E. coli* species. pBR322 contains genes for ampicillin and tetracycline resistance and thus provides easy means for identifying transformed cells.
15 The pBR plasmid, or other microbial plasmid or phage must also contain, or be modified to contain, promoters which can be used by the microbial organism for expression of its own proteins.

20 In addition, phage vectors containing replicon and control sequences that are compatible with the host microorganism can be used as transforming vectors in connection with these hosts. For example, the phage lambda GEMTM-11 may be utilized in making a recombinant
25 phage vector which can be used to transform host cells, such as *E. coli* LE392.

 Those promoters most commonly used in recombinant DNA construction include the B-lactamase (penicillinase),
30 lactose promoter systems, and a tryptophan (*trp*) promoter system. While these are the most commonly used, other microbial promoters have been discovered and utilized, and details concerning their nucleotide sequences have been published, enabling a skilled worker to ligate them
35 functionally with plasmid vectors (Sambrook et al., 1989).

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It is similarly believed that almost any eukaryotic expression system may be utilized for the expression of the flagellin gene; e.g., *Saccharomyces*, *Baculovirus*, SV40, Adenovirus, glutamine synthase-based or dihydrofolate reductase-based systems could be employed. For example, plasmid vectors incorporating an origin of replication and an efficient eukaryotic promoter will be of most use. Advantages of a eukaryotic expression system include the ease of producing a large amount of protein and avoidance of contamination with any bacterial products that may be bound by antibodies in sera.

For expression in this manner, one would position the coding sequences adjacent to and under the control of the promoter. It is understood in the art that to bring a coding sequence under the control of a promoter, one positions the 5' end of the transcription initiation site of the transcriptional reading frame of the protein between about 1 and about 50 nucleotides "downstream" of (i.e., 3' of) the chosen promoter.

Where eukaryotic expression is contemplated, one will also typically desire to incorporate into the transcriptional unit which includes the flagellin gene, an appropriate polyadenylation site (e.g., 5'-AATAAA-3') if one was not contained within the original cloned segment. Typically, the poly A addition site is placed about 30 to 2000 nucleotides "downstream" of the termination site of the protein at a position prior to transcription termination.

Table 2 provides a listing of those *B. lonestari* sp. nov.-specific nucleotides and species-specific combination(s) of nucleotides of the flagellin gene of *B. lonestari* sp. nov. These nucleotides represent variations in their respective positions compared to the

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corresponding available sequences of other *Borrelia* species.

Table 3 provides a listing of those species-specific nucleotides and species-specific combination(s) of nucleotides of the 16s rRNA gene of *B. lonestari* sp. nov. These nucleotides represent variations in their respective positions compared to the corresponding available rRNA sequences of other *Borrelia* species.

10

The *B. lonestari* sp. nov.-specific nucleotides or species-specific combination of nucleotides of this new spirochete, both from the flagellin and the rRNA genes, provide unique nucleotide targets for assay for identification of the organism. Nucleotide assays that are contemplated include:

15

i) For both the flagellin and rRNA genes, the nucleotide sequence of a segment containing any of the species-specific nucleotides or species-specific combination of nucleotides of Tables 2 or 3 clearly determines the identity of the sample being examined. A region containing the species-specific nucleotides or species-specific combination of nucleotides would be amplified by a polymerase chain reaction (PCRTM) and used for standard nucleotide sequence analysis as described in Example 2 and 3.

20

25

ii) For the flagellin gene, hybridization of species-specific oligonucleotide probes to a sample being analyzed will identify the sample. The species-specific nucleotide probe would be complementary to and would hybridize with areas of the nucleotide sequence provided in SEQ ID NO:1 having a species-specific nucleotide or species-specific combination of nucleotides as shown in Table 2. Preferred nucleotide probes would be

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complementary to and, therefore, hybridize with those regions of the *B. lonestari* sp. nov. sequence that are species-specific due to deletions of nucleotides from the flagellin gene of related *Borrelia* species (Table 2).

iii) Restriction fragment length polymorphism analysis of a sample of DNA from an infected human, or DNA from a tick or the spirochete will determine identity of the *Borrelia* species.

Each of these nucleotide assay embodiments is discussed in further detail as follows.

PCRTM amplification and DNA sequence analysis

DNA primers that would be useful in PCRTM may be derived from any portion of SEQ ID NOS:1 or 3 as long as one primer is 5' to a species-specific nucleotide or species-specific combination of nucleotides and a second primer is 3' to the same species-specific nucleotide or combination. PCRTM primers generally are about at least 13 nucleotides in length and may be up to 20 or 25 or 30 nucleotides or even longer, and the region primed and amplified may range from about 50 nucleotides to about 2000 nucleotides. A preferred amplified product is about 100 to 300 or 400 nucleotides long.

Nucleic acid sequencing is carried out using the dideoxy chain termination technique (Sanger et al., 1977, and Sambrook et al., 1989). One skilled in this art would be familiar with the PCRTM amplification procedure and nucleic acid sequencing and would know, in light of the present disclosure, how to use the sequences provided herein to amplify regions of the flagellin gene and the rRNA gene to obtain PCRTM products for nucleotide

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sequencing. Examples of these procedures are provided in Examples 2 and 3.

Oligonucleotide Probes for Hybridization

5

An oligonucleotide probe of the present invention for hybridization to determine identity of a clinical sample is a nucleotide sequence of SEQ ID NO:1 that is complementary to a region of the flagellin gene having a
10 *B. lonestari* sp. nov.-specific nucleotide or species-specific combination of nucleotides of Table 2 within that region. One skilled in this art would also realize that the complement of the oligonucleotide would also detect that region of sequence by binding to the opposite
15 strand of DNA.

The probe may be from about 13 nucleotides in length up to and including the full length sequence, preferably is about 13-30 nucleotides in length and is most
20 preferably from about 15 to about 18, 19, 20 or 21 nucleotides in length. The oligonucleotide binds to its complement under standard hybridization conditions. The term "standard hybridization conditions" as used herein, is used to describe those conditions under which
25 substantially complementary nucleic acid segments will form standard Watson-Crick base-pairing. A number of factors are known that determine the specificity of binding or hybridization, such as pH, salt concentration, the presence of chaotropic agents (e.g. formamide and
30 dimethyl sulfoxide), the length of the segments that are hybridizing, and the like.

For use with the present invention, standard hybridization conditions for relatively large segments,
35 that is segments longer than about 100 nucleotides, will include a hybridization mixture having between about 0.3 to 0.6 M NaCl, a divalent cation chelator (e.g. EDTA at

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about 0.05mM to about 0.5 mM), and a buffering agent (e.g. Na_2PO_4 at about 10mM to 100 mM, pH 7.2), at a temperature of about 65° C. The preferred conditions for hybridization are a hybridization mixture comprising 0.5 M NaCl, 5mM EDTA, 0.1 M Na_2PO_4 , pH 7.2 and 1% N-lauryl sarcosine, at a temperature of 65°C. Naturally, conditions that affect the hybridization temperature, such as the addition of chaotropic agents, such as formamide, will be known to those of skill in the art, and are encompassed by the present invention.

When it is contemplated that shorter nucleic acid segments will be used for hybridization, for example fragments between about 15 and about 30 nucleotides, salt and temperature conditions will be altered to increase the specificity of nucleic acid segment binding. Preferred conditions for the hybridization of short nucleic acid segments include lowering the hybridization temperature to about 37°C, and increasing the salt concentration to about 0.5 to 1.5 M NaCl with 1.5 M NaCl being particularly preferred.

For applications requiring high selectivity, one will typically desire to employ relatively stringent conditions to form the hybrids, e.g., one will select relatively low salt and/or high temperature conditions, such as provided by 0.02M-0.15M NaCl at temperatures of 50°C to 70°C. Such selective conditions tolerate little, if any, mismatch between the probe and the template or target strand, and would be particularly suitable for a diagnostic assay.

Oligonucleotides for use as probes may be readily prepared by, for example, directly synthesizing the fragment by chemical means, by application of nucleic acid reproduction technology, such as the PCRTM technology of U.S. Patent 4,683,202 and 4,683,195 (herein

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incorporated by reference) or by introducing selected sequences into recombinant vectors for recombinant production.

5 In certain embodiments, it will be advantageous to employ nucleic acid sequences of the present invention in combination with an appropriate means, such as a label, for determining hybridization. A wide variety of appropriate indicator means are known in the art,
10 including fluorescent, radioactive, enzymatic or other ligands, such as avidin/biotin, that are capable of giving a detectable signal. In preferred embodiments, one will likely desire to employ a fluorescent label or an enzyme tag, such as urease, alkaline phosphatase or
15 peroxidase, instead of radioactive or other environmental undesirable reagents. In the case of enzyme tags, colorimetric indicator substrates are known which can be employed to provide a means visible to the human eye or spectrophotometrically, to identify specific
20 hybridization with complementary nucleic acid-containing samples.

 In general, it is envisioned that the hybridization probes described herein will be useful both as reagents
25 in solution hybridization as well as in embodiments employing a solid phase. In embodiments involving a solid phase, the test DNA (or RNA) is adsorbed or otherwise affixed to a selected matrix or surface. This fixed, single-stranded nucleic acid is then subjected to
30 specific hybridization with selected probes under desired conditions. The selected conditions will depend on the particular circumstances based on the particular criteria required (depending, for example, on the G+C content, type of target nucleic acid, source of nucleic acid, size
35 of hybridization probe, etc.). Following washing of the hybridized surface so as to remove nonspecifically bound

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probe molecules, specific hybridization is detected, or even quantified, by means of the label.

Restriction Fragment Length Polymorphism

5
Analyses of the sequence provided in SEQ ID NOS:1 and 3 indicate that different patterns of products are found when the *B. lonestari* sp. nov. DNA is cleaved by a restriction enzyme compared to the restriction patterns
10 obtained from other species of *Borrelia*. In particular, as shown in Example 2, an *AluI* digest of an about 330 bp PCRTM product (SEQ ID NO:4) and electrophoretic analysis of the enzyme digest yielded characteristic restriction fragments for different species of *Borrelia*, including *B.*
15 *burgdorferi* B31, from two North American relapsing fever agents *B. hermsii* HS1 and *B. turicatae* "Ozona", and from immunofluorescence-positive *Amblyomma* ticks from Texas and New Jersey. The gel patterns of the two *Amblyomma* tick samples both differed from the digested products
20 from *B. burgdorferi*, *B. hermsii*, and *B. turicatae*. Further enzyme digests that demonstrate polymorphisms are shown in Table 7 of Example 5. DNA is prepared from a sample for RFLP analysis as described in Examples 2 and 3. Primers are hybridized to the DNA and the PCRTM
25 reaction carried out also substantially as described in those examples. One skilled in the art would know that other primers may be used, especially if the DNA fragment to be amplified is cloned into a vector of known sequence. A restriction enzyme digest is carried out
30 choosing from those enzymes of Table 7, and the digest applied to, preferably, an agarose gel. Visualization of the restriction enzyme fragments and comparison of their sizes with those listed in Table 7 provide identification of the *Borrelia* species.

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The following examples are included to demonstrate preferred embodiments of the invention. It should be

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appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the practice of the invention, and thus
5 can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result
10 without departing from the spirit and scope of the invention.

EXAMPLE 1

EVIDENCE FOR A SPIROCHETE IN *A. AMERICANUM* THAT 15 CROSS-REACTS WITH ANTI-*B. BURGDORFERI* ANTISERUM

The present example provides evidence for a spirochete in *A. americanum* that cross-reacts with anti-*B. Burgdorferi* antiserum at high concentrations of the
20 antiserum.

For the present study, *A. americanum* ticks were collected from field locations in Missouri, New Jersey, New York, North Carolina, and Texas and examined with
25 anti-*B. burgdorferi* polyclonal antisera in concentrations giving cross-reactions with other *Borrelia* spp. (Maupin et al., 1991). Fluorescent photomicrographs were taken of *B. turicatae*, a relapsing fever agent, and spirochetes in the crushed midgut of an *A. americanum* tick stained
30 with a 1:10 dilution of fluorescein isothiocyanate-conjugated rabbit antibodies to *B. burgdorferi* (Maupin et al., 1991). Approximately 2% of the ticks, both nymphs and adults, in Missouri, New Jersey, New York, and North Carolina contained immunoreactive spirochetes of
35 between 10 and 20 μ m in length as shown in Table 4. The results for the Texas organisms were similar.

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TABLE 4

Presence of immunofluorescence-reactive spirochetes
in *Amblyomma americanum* nymphal and adult ticks*

LOCATION	# POSITIVE (adults)	# EXAMINED (adults)
Monmouth Co., NJ	3 (2)	110 (50)
Suffolk Co., NY	10 (9)	375 (318)
Currituck Co., NC	1 (0)	95 (26)
Southeast MO†	6 (0)	295 (29)
Total	20 (11)	875 (423)
% positive [range]	2.3% [1.1-2.7%]	

*Reactive with 1:10 dilution of fluorescein-conjugated antiserum to *B. burgdorferi* (Maupin et al., 1991). The spirochete was not detected with a 1:100 dilution of the antiserum.

†Bollinger Co., Pulaski Co., and Stoddard Co., MO

To characterize the *A. americanum* spirochete, attempts were made to cultivate it in media that supports the growth of several *Borrelia* spp., including those that cause Lyme disease and several that cause relapsing fever (Barbour, 1984). In addition, some samples with the suspected agent were injected into laboratory mice, which were subsequently examined for illness and their organs were cultured. These attempts, like those in the past (Schulze et al., 1984; Kocan et al., 1992), failed to isolate the organism in the laboratory.

EXAMPLE 2

THE *A. AMERICANUM* SPIROCHETE IS A NEW *BORRELIA*
SPECIES, *B. LONESTARI* SP. NOV.

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The present example describes the inventors' analysis of the *A. americanum* spirochete that led to their determination that the spirochete is a new *Borrelia* species.

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The present inventors used the polymerase chain reaction (PCRTM) and amplification of conserved genes using primers designed on the basis of sequences of possibly-related organisms (Relman, 1993). The genes for
5 16S rRNA and flagellin, the major structural protein of flagella, of several *Borrelia* spp. were available, and alignment revealed regions of genus-specific sequences.

A. americanum ticks were collected in New Jersey and
10 New York from the field by flagging. Flagging is a technique described in Maupin et al., (1991) which reference is specifically incorporated herein by reference. *A. americanum* ticks from Texas had been removed from human hosts and submitted to the Department
15 of Health. Ticks were dissected with sterile instruments, and portions of their midguts were examined by direct fluorescent microscopy with polyclonal antiserum to *B. burgdorferi* (Maupin et al., 1991). DNA from positive and negative ticks was extracted at two
20 locations using different extraction methods: (a) Ticks from New York and New Jersey were individually placed in sterile plastic bags, frozen, and crushed. To the homogenate was added, first, 0.5 ml of 10 mM Tris, pH 8.0-1 mM EDTA (TE) with 0.1 mg/ml of yeast tRNA and 1%
25 sodium dodecyl sulfate (SDS) and, then, 0.5 ml of phenol. The aqueous phase was extracted with ether. (b) Ticks from Texas were placed in sterile microfuge tubes. To the tube was added 0.2 ml of 10 mM Tris, pH 8.0-50 mM EDTA-2% SDS. The suspension was heated to 64°C for 20
30 min, extracted with phenol, and twice with chloroform. The DNA obtained by both methods was precipitated with ethanol and resuspended in TE. The investigator who performed the PCRTM was blind to the findings of the tick examinations.

35

The sequence of a first set of PCRTM primers (FlaLS and FlaRS) was based on identical sequences in flagellin

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of *Borrelia* spp. The positions listed in parentheses following the sequence refer to *B. burgdorferi* flagellin (Fla) gene:

5 FlaLS: 5'AACAGCTGAAGAGCTTGAATG3' (438-459); SEQ ID
NO:9 FlaRS: 3'CGATAATCTTACTATTCACTAGTTTC5' (766-791);
SEQ ID NO:10. The primers differed in sequence at two or
more positions from homologous sequences of other
spirochetes and bacteria. This first set of primers was
10 expected to amplify a ~330 base-pair fragment of the
flagellin gene of any *Borrelia* spp.

 PCRTM primers were synthesized as follows. PCRTM
reactions in volumes of 100 µl containing 2.5 U of Taq
15 DNA polymerase (Boehringer-Mannheim), 50 pmole of each
primer, 200 µM of each dNTP, 10 mM Tris (pH 8.3), 50 mM
KCl, 1.5 mM MgCl₂, and 0.001% gelatin were carried out in
Perkin-Elmer-Cetus thermal cycler. The reaction program
was first 95°C for 3 min and then 40 cycles of 95°C for 1
20 min, 55°C for 1 min., and 75°C for 1 min.

 Subsequent AluI restriction enzyme digestion of the
PCRTM products and electrophoretic analysis of the enzyme
digest (4% NuSieveTM gel, FMC, (Rockland, Maine) with
25 Tris-acetate-EDTA buffer) yielded characteristic
restriction fragments for different species of *Borrelia*,
including *B. burgdorferi* B31, from two North American
relapsing fever agents *B. hermsii* HS1 and *B. turicatae*
"Ozona", and from immunofluorescence-positive *Amblyomma*
30 ticks from Texas and New Jersey. The gel patterns of the
two *Amblyomma* tick samples revealed fragments of about
117, 85 and 55 base pairs; from *B. burgdorferi*, about 130
and 106 base pairs; from *B. hermsii*, about 160, 100 and
75 base pairs; and from *B. turicatae*, about 110 and 75
35 base pairs.

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PCRTM products from one of the Texas ticks and one of the New Jersey ticks were cloned into vector pCRIITM using the TA Cloning System and *E. coli* strain INV α F' (Invitrogen, San Diego, CA). Sequences of both strands from at least two clones of each PCRTM product were determined from double-stranded DNA using SEQUENASETM version 2.0 (U.S. Biochemical, Amersham Life Sci, Arlington Heights, Illinois) and custom-synthesized primers. The sequence of this ~330 base region is provided as SEQ ID NO:4. Both sequences were confirmed to be the central portion of a flagellin gene, but they were not identical to comparable regions of other *Borrelia* spp. flagellin genes in the sequence databases (see Example 3).

To assess the specificity of the PCRTM reaction, additional extracts from *A. americanum* ticks from New York were examined. For this study, extracted DNA was subjected to PCRTM with primer pairs FlaSL and FlaSR. The PCRTM products were subjected to Southern blot analysis by separating the products in a 0.9% GTGTM agarose gel (FMC) in Tris-borate-EDTA buffer, and, after transfer to 0.22 mm NytranTM membranes (Schleicher & Schuell, Keene, New Hampshire), probed with the PCRTM product from the Texas tick. The probe was labeled with [³²P]-dATP using a nick translation kit (Gibco/BRL, Gathersburg, Maryland). Prehybridization was carried out in hybridization medium (6xSSC, 5x Denhardt's, 0.5% SDS, 100 μ g/ml denatured salmon sperm DNA, 50% formamide to 200ml with water) for 1-4 h at 37°. The probe was added and hybridization was carried out overnight at 37°. The first and second washes were with 2xSSC, 0.1% SDS, 1mM EDTA, for 5 min at room temperature. The third and fourth washes were with 100-200 ml of 0.1xSSC, 0.1% SDS, 1mM EDTA, for 15-30 min at 64° C. The final wash was with 0.1xSSC at room temperature. X-ray film was exposed with an intensifying screen. Nine of 10 extracts from ticks

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that were positive by direct fluorescence assay with conjugated rabbit antibody to *B. burgdorferi* (Maupin et al., 1991) had products that detectably hybridized with the probe; none of 11 ticks that were negative by the direct fluorescence assay hybridized with the probe (p < 0.0001 by two-tailed Fisher exact test). This test indicates that the DNA obtained by the PCRTM reaction was specific for anti-*Borrelia*-positive spirochetes. This new *Borrelia* species was named *B. lonestari* sp. nov. The anti-*B. burgdorferi* antibody, at high concentrations, cross-reacts with all *Borrelia* species, whereas a DNA probe of the present invention is expected to bind only *B. lonestari* sp. nov. samples.

EXAMPLE 3

REGIONS OF *B. LONESTARI* SP. NOV. FLAGELLIN GENE
AND rRNA GENE SEQUENCES DIFFER FROM THOSE OF
OTHER *BORRELIA* SP.

The present example describes those regions of the *B. lonestari* sp. nov. flagellin amino acid and rRNA sequences that differ from those of other *Borrelia* sp.

With the inventors' collection of evidence that the *Amblyomma* spirochete was a new *Borrelia* sp., sets of primers were used to amplify a larger region of the flagellin gene and most of the 16S rRNA gene. The primers were based on identical sequences in flagellin and 16S rRNA genes of *Borrelia* spp. The primers differed in sequence at two or more positions from homologous sequences of other spirochetes and bacteria. In the following primer sequences, the positions listed in parentheses refer to *B. burgdorferi* flagellin (Fla) and 16S rRNA (16Rna) genes:

FlaLL, 5'ACATATTCAGATGCAGACAGAGGT3' (301-324); SEQ
ID NO:11

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FlaRL, 3'TGTTAGACGTTACCGTTACTAACG5' (942-965); SEQ
ID NO:12

16RnaL, 5'CTGGCAGTGCGTCTTAAGCA3' (36-55); SEQ ID
5 NO:13

16RnaR, 3'CATATAGTCTTACTATGCCACTTAG5' (1346-1368).
SEQ ID NO:14

10 PCRTM primers were synthesized as described in Example 2.

PCRTM products from organisms in ticks from Texas
and New Jersey were sequenced over both strands and as
different recombinant clones. PCRTM products were
15 obtained with primer pairs FlaLS+FlaRS, FlaLL+FlaRL, and
16RnaR+16RnaL and cloned into vector pCRIITM using the TA
Cloning System and *E. coli* strain INVαF' (Invitrogen).
Sequences of both strands from at least two clones of
each PCRTM product were determined from double-stranded
20 DNA using Sequenase version 2.0 (U. S. Biochemical) and
custom-synthesized primers. The nucleotide sequence of
the flagellin fragment is assigned SEQ ID NO:1 and
contains about 70% of the flagellin gene; the deduced
amino acid sequence is assigned SEQ ID NO:2. This
25 fragment contains the variable portion of the sequence of
bacterial flagellin genes and is the region that contains
species-specific epitopes or species-specific combination
of epitopes of the flagellin protein.

30 Three PCRTM clones of the Texas tick, positioned in
the vector pCRIITM and in the host *E. coli* strain INVαF'
(Invitrogen), were sequenced for comparison to neutralize
errors made by the polymerase enzyme in this method.
These clones are designated as follows: i) clone 70,
35 named pTxfla70, deposited with the American Type Culture
Collection, 12301 Parklawn Drive, Rockville, Maryland,
20852 as ATCC #69818; the sequence from this tick is SEQ

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ID NO: 28 and has a "A" at position 345 instead of a "G" as shown in SEQ ID NO: 1; ii) clone 69 which has an "A" at position 345, a "C" at position 573, and a "T" at position 586 compared to SEQ ID NO: 1; and iii) clone 5 which has a "T" at position 3, and a "T" missing at position 24 compared to SEQ ID NO: 1. A composite sequence, obtained by comparison of these clones, and comparison with other *Borrelia* sequences, is provided as SEQ ID NO: 1.

10

The sequence of the new spirochete from New Jersey differed from that of the Texas tick in two locations, 1) base #345 of SEQ ID NO:1 is an A for the New Jersey tick, but a G for the Texas tick; this change does not alter the encoded amino acid; 2) base #591 of SEQ ID NO:1 is a G for the New Jersey tick, but an A for the Texas tick; this change also does not alter the amino acid sequence. Neither variation is near part of the flagellin gene where species-specific nucleotides are found or where species-specific amino acids are encoded. This variation may be considered an idiosyncrasy among this species.

The obtained nucleotide and deduced amino acid sequences were used to search by the BLAST algorithm the daily-updated sequence databases managed by the National Center for Biotechnology Information (Altschul et al., 1990). No identical matches were found to flagellin and rRNA genes of *Borrelia* spp.

The alignment of the deduced partial flagellin proteins of *Amblyomma* spirochete strains from Texas and New Jersey is shown in Table 5 with the comparable variable regions of the flagellin proteins of eight *Borrelia* spp.

35

TABLE 5

Alignment of variable regions of spirochete flagellin proteins,
sequences in bold type have sequence identifiers as indicated¹.

	73*	80	90	100	110	120	130
AbTx_Fla [†] :	LRVQVGANQDEAIAVNIFSTNVANLFGGEGV...	QAAPAQEGAQQEGVQP...	APAQGGISSPINVTTAIDAN				
AbNJ_Fla:							
Bt_Fla:	H	YAA	A	A	VS	AAPAPAA	VN-V-T
Bp_Fla:	H	YAS	A	A	VS	AAPAPAA	VN-V-TV
Ba_Fla:	H	YAA	A	A		ATPAPVA	P-VN-I-V
Bh_Fla:	H	YAS	A	A	V-IG	EG-AAPAPAA	VN-V
Bc_Fla:	H	YAA	S	AQ	V	A-AAPAPAS	VN-V
Bz_Fla:	H	YAA	A	AQAA	V	E-A-Q-PTPAT	T-VN-V-TV
Bg_Fla:	H	YAA	S	AQAA	TA-V	A-Q-PAPVT	S-VN-V-TV
Bb_Fla:	H	YAA	S	AQTA	V	A-Q-PAPAT	S-VN-V-TV

¹LRVQVGANQDEAIAVNIFSTNVANLFGGEGV; SEQ ID NO:15

QAAPAQEGAQQEGVQP; SEQ ID NO:16

APAQGGISSPINVTTAIDAN; SEQ ID NO:17

AAPAPAA; SEQ ID NO:18

ATPAPVA; SEQ ID NO:19

TABLE 5 (continued)

AAPAPAS; SEQ ID NO:20
 AQAA; SEQ ID NO:21
 PTPAT; SEQ ID NO:22
 PAPVT; SEQ ID NO:23
 AQTA; SEQ ID NO:24
 PAPAT; SEQ ID NO:25

*Numbers correspond to amino acid positions of *B. lonestari* sp. nov. flagellin protein fragment of SEQ ID NO:2.

†Abbreviations and sources (accession numbers): Ab, *Amblyomma borrelia* strains from Texas and New Jersey; Bt, *B. turicatae* (M67462); Bp, *B. parkeri* (M67461); Ba, *B. anserina* (X75201); Bh, *B. hermsii* (A44894 and M67460); Bc, *B. crocidurae* (X75204); Bz, *B. afzelii*; Bg, *B. garinii* (X75203); Bb, *B. burgdorferi* (X69611 and P11089); and Fla, flagellin.

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The flagellin proteins of these organisms differed from other borrelial flagellins at several positions and, uniquely among the *Borrelia* spp., lacked most of a proline-alanine-rich region beginning around nucleotide
5 residue 119 of SEQ ID NO:2.

Phylogenetic classification was provided by distance matrix analysis and by comparison of 16S rRNA gene sequences (Table 6).

10

TABLE 6
Signature base positions of 16S rRNA genes of *Borrelia* spp.¹

Base ² :	42	91	135	146	217	224	267	435	437	522	554	564	963	1074	1143	1215
Base ³ :	77	126	170	181	253	260	303	471	473	558	590	600	999	1110	1179	1251
Ab_rna:T	C	A	A	T	A	A	G	T	G	T	C	T	T	A	G	A
Bm_rna:T	C	A	A	A	G	G	G	T	A	C	C	C	T	A	G	A
Bf_rna:C	T	G	A	A	A	A	G	A	G	T	T	T	C	G	A	G
Bh_rna:C	T	G	A	A	A	A	A	A	A	T	T	C	C	G	A	A
Ba_rna:C	T	G	A	A	G	A	A	A	A	C	T	C	C	G	A	G
Bb_rna:C	T	G	G	T	A	A	A	A	A	T	T	T	C	A	G	A

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¹The GenBank accession number for the 16S rRNA gene sequence is U23211. Abbreviations: Ab, *Amblyomma* tick borrelia, Texas and New Jersey strains; Bm, *B. miyamotoe* sp. nov.; Bf, Florida canine borrelia; Bh, *B. hermslii*; Ba, *B. anserina*; Bb, *B. burgdorferi*. Sources for sequences are given in legend for Table 5.

²Base position corresponding to SEQ ID NO:3, the partial 16S rRNA sequence of *B. lonestari* sp. nov.

³Base positions correspond to positions of 16S rRNA gene of *B. burgdorferi*. Nine of the 16 positions are predicted to be in non-base paired regions of the 16S rRNA.

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The 16S rRNA gene sequences of the Texas and New Jersey strains differed at only 2 out of 1336 nucleotide positions. Positions 733 and 739 have a T and G in those positions, respectively, in the Texas strain but a C and C in those positions, respectively, for the New Jersey strain. These residues are not considered to be species-specific nucleotides. A clone of the Texas strain designated pTxrna20, positioned in the vector pCRIITM and in the host *E. coli* strain INV α F' (Invitrogen), was deposited in the American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland, 20852 as ATCC #69819. By distance matrix and parsimony analyses of the aligned sequences, the *Amblyomma* spirochetes represented a different species of *Borrelia*. The organism is in a group containing relapsing fever species. Parsimony analysis of base positions that were polymorphic in at least two of 6 species yielded a similar result (Table 6). Among the 6 sequences represented in Table 6, there were 49 aligned positions at which only one of the 6 species differed; 27 (53%) of these differences were in *B. burgdorferi*.

Other organisms in the relapsing fever group are the bird pathogen *B. anserina*, an unnamed organism recovered from the blood of two dogs in Florida, and a bacterium identified as *B. miyamotae* sp. nov. and isolated from *I. persulcatus* ticks in Japan (accession number D45192). By both distance matrix and parsimony analysis, *B. lonestari* sp. nov. is most closely related to *B. miyamotae* sp. nov., another *Borrelia* associated with hard rather than soft ticks. All *Borrelia* sp. identified to date infect vertebrates as well as arthropods (Barbour et al., 1986).

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EXAMPLE 4

A FUSION PROTEIN COMPRISING A PORTION OF
B. lONESTARI SP. NOV. FLAGELLIN

5 The present example describes the placement of the
nucleotide sequence represented by SEQ ID NO:1 into a
construct to provide a fusion protein for immunoassay.
This construct supplies an N-terminus and a C-terminus
for the recombinant fusion protein. The pMALTM p2
10 expression vector, obtained from New England Biolabs,
(Beverly, MA) and encoding the maltose binding protein,
was used for this construct. The vector was digested
with *EcoRI* and *XbaI*, ligated to the nucleic acid having
SEQ ID NO:1, and having an in-frame stop codon and
15 synthetic *EcoRI* and *XbaI* sequences added; and the
recombinant molecule transfected into *E. coli* JM103.
Methods for protein fusion and purification are described
in the New England Biolabs brochure (1992). The
resulting construct is represented by the partial
20 sequence of SEQ ID NO:26. A fusion protein is made that,
when cleaved with a blood protease factor Xa, releases
flagellin protein having an additional Ile Ser Glu Phe
(SEQ ID NO:27) sequence at the N-terminus and an
additional Ala Val sequence at the C terminal end.

25 An antigen with minimal or no cross-reactivity with
B. burgdorferi is desirable since the skin rash
associated with the bite of *Amblyomma americanum* ticks is
similar to erythema migrans, the skin rash of early Lyme
30 disease. Therefore, a practitioner observing the skin
rash may make an initial diagnosis of Lyme disease. An
ELISA test, Western blot assay or similar assay for
antibodies which could distinguish between infections
with *B. lonestari* and/or *B. burgdorferi* is desirable
35 because the infection with these microorganisms may be
indistinguishable on the basis of a skin rash or other

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clinical features. Therefore, a *Borrelia* gene encoding a flagellin protein, such as, *Borrelia crocidurae*, a relapsing fever agent of Eurasia, could provide the N- and C-terminal structure for the incorporation of the nucleotide sequence of the *B. lonestari* sp. nov. The resultant fused protein product, a recombinant, chimeric flagellin, would minimize cross-reactivity with antibodies to other *Borrelia* and spirochetes among patients samples in North America and would be a principal reagent in an ELISA test, Western blot assay or similar assay for antibodies to *B. lonestari* sp. nov. in patients and domestic animals suspected of harboring this agent. An advantage of a *B. lonestari* sp. nov. fusion protein having N- and C-terminal ends from another flagellin protein is that the fusion protein will more likely fold properly as a flagellin protein, its conformation will be more likely like that of the natural form, and it is expected to be easier to purify. The fusion protein may be purified according to Barbour et al., for example.

EXAMPLE 5

RESTRICTION FRAGMENT LENGTH POLYMORPHISMS FOR ASSAY OF SPECIMENS FOR PRESENCE OF *B. LONESTARI* SP. NOV.

The present Example provides for analyses of the sequences provided in SEQ ID NOS:1 and 3 to indicate that different patterns of products are found when the *B. lonestari* sp. nov. DNA is cleaved by a restriction enzyme compared to the restriction patterns obtained from other species of *Borrelia*. This method allows for the identification not only of the new spirochete, but also of the other *Borrelia* species.

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As shown in Example 2, an AluI digest of an about 330 bp PCRTM product (SEQ ID NO:4) and electrophoretic analysis of the enzyme digest yielded characteristic restriction fragments for different species of *Borrelia*, including *B. burgdorferi* B31, from two North American relapsing fever agents *B. hermsii* HS1 and *B. turicatae* "Ozona", and from immunofluorescence-positive *Amblyomma* ticks from Texas and New Jersey. The gel patterns of the two *Amblyomma* tick samples revealed fragments of about 117, 85 and 55 base pairs; from *B. burgdorferi*, about 130 and 106 base pairs; from *B. hermsii*, about 160, 100 and 75 base pairs; and from *B. turicatae*, about 110 and 75 base pairs. Therefore, when appropriate size standards are included in an electrophoretic gel analysis, an approximation of the sizes and numbers of restriction fragments is sufficient to identify the *Borrelia* species.

Further enzyme digests that demonstrate polymorphisms are shown in Table 7. The data provided in Table 7 are for a PCRTM amplified product using PCRTM primers of SEQ ID NO. 11 and 12 or are from the whole gene (Ba, Bc, Bz).

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TABLE 7
Restriction Fragment Length Polymorphisms for the
Flagellin Gene of Various *Borrelia* Species¹

	BlT	Bb	Bh	BlNJ	Ba	Bc	Bz
AluI	150	352	346	150	323	176	261
	131	130	160	131	177	166	237
	130	106	100	130	159	159	137
	117	50	55	117	132	147	92
	55	31		55	69	138	69
	36			36	55	92	69
					48	69	62
					42	55	55
					39	45	45
						36	33
NdeI	540	-	467	540	604	607	-
	101		101 90	101	508	508	
NheI	511	-	-	511	604	945	-
	130			130	508	176	
DpnI	384	407	460	384	373	357	489
	180	180	131	180	281	284	287
	77	77	67	77	226	226	226
					121	117	121
					111	81	
						40	

¹Sizes of fragments in base pairs are shown for each enzyme digest of a PCRTM amplified product using SEQ ID NO:11 and 12 as PCRTM primers or from the whole gene (Ba, Bc, Bz). Fragments shorter than 30 base pairs are not listed. Abbreviations and sources (accession numbers): BlT, BlNJ *Borrelia lonestari* strains from Texas and New Jersey; Bb, *B. burgdorferi* (X69611 and P11089); Bh, *B. hermsii* (A44894 and M67460); Ba, *B. anserina* (X75201); Bc, *B. crocidurae* (X75204); Bz, *B. afzelii*.

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EXAMPLE 6**METHOD OF ASSAYING A CLINICAL SAMPLE**

5 The present Example provides methods for the assay
of a clinical sample for the determination of the
presence or absence of *B. lonestari* sp. nov. A clinical
sample may be a tick suspected of harboring the new
Borrelia species, for example, or clinical samples
obtained from a patient such as blood or serum samples, a
10 skin biopsy, cerebrospinal fluid, or urine samples. A
preferred sample is a blood or CSF sample for antibody or
T cell assays. An immunoassay would be carried out on a
patient sample of whole cells or sonicated cell extract,
for example, using flagellin specific antiserum to test
15 for the presence of species-specific antigens. For
nucleic acid assays, the nucleic acid, either RNA or DNA,
would be amplified using a PCRTM reaction, for example,
or an amplification procedure that would achieve a
similar end, and the product analyzed as described
20 herein. Reverse transcriptase may be used to make a cDNA
copy of a messenger RNA molecule for amplification or
ribosomal RNA may be obtained in a straightforward manner
since it is abundant in the cell.

25

EXAMPLE 7**VACCINES FOR PROTECTION AGAINST*****B. LONESTARI* SP. NOV. INFECTION**

30 The present inventors contemplate vaccines for use
in both active and passive immunization embodiments.
Immunogenic compositions, proposed to be suitable for use
as a vaccine, may be prepared most readily directly from
immunogenic *B. lonestari* sp. nov.-specific surface
antigens, such as Vmp or Osp lipoprotein. Preferably,
35 the antigenic material is purified by column
chromatography, such as HPLC. The material may be

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dialyzed to remove undesired small molecular weight molecules and/or lyophilized for ready formulation into a desired vehicle.

5 The preparation of vaccines that contain peptide sequences as active ingredients is generally well understood in the art, as exemplified by U.S. Patents 4,608,251; 4,601,903; 4,599,231; 4,599,230; 4,596,792; and 4,578,770, all incorporated herein by reference.

10 Typically, such vaccines are prepared as injectables, either as liquid solutions or suspensions. Solid forms suitable for solution in, or suspension in, liquid prior to injection may also be prepared. The preparation may also be emulsified. The active immunogenic ingredient is

15 often mixed with excipients that are pharmaceutically acceptable and compatible with the active ingredient. Suitable excipients are, for example, water, saline, dextrose, glycerol, ethanol, or the like, and combinations thereof. In addition, if desired, the

20 vaccine may contain minor amounts of auxiliary substances such as wetting or emulsifying agents, pH buffering agents, or adjuvants which enhance the effectiveness of the vaccines.

25 Vaccines may be conventionally administered parenterally, by injection, for example, either subcutaneously or intramuscularly. Additional formulations which are suitable for other modes of administration include suppositories and, in some cases,

30 oral formulations. For suppositories, traditional binders and carriers may include, for example, polyalkylene glycols or triglycerides: such suppositories may be formed from mixtures containing the active ingredient in the range of 0.5% to 10%, preferably

35 1-2%. Oral formulations include such normally employed excipients as, for example, pharmaceutical grades of

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mannitol, lactose, starch, magnesium stearate, sodium
saccharine, cellulose, magnesium carbonate and the like.
These compositions take the form of solutions,
suspensions, tablets, pills, capsules, sustained release
5 formulations or powders and contain 10-95% of active
ingredient, preferably 25-70%.

The proteins or peptides may be formulated into the
vaccine as neutral or salt forms. Pharmaceutically
10 acceptable salts, include the acid addition salts (formed
with the free amino groups of the peptide) and those
which are formed with inorganic acids such as, for
example, hydrochloric or phosphoric acids, or such
organic acids as acetic, oxalic, tartaric, mandelic, and
15 the like. Salts formed with the free carboxyl groups may
also be derived from inorganic bases such as, for
example, sodium, potassium, ammonium, calcium, or ferric
hydroxides, and such organic bases as isopropylamine,
trimethylamine, 2-ethylamino ethanol, histidine,
20 procaine, and the like.

The vaccines are administered in a manner compatible
with the dosage formulation, and in such amount as will
be therapeutically effective and immunogenic. The
25 quantity to be administered depends on the subject to be
treated, including, e.g., the capacity of the
individual's immune system to synthesize antibodies, and
the degree of protection desired. Precise amounts of
active ingredient required to be administered depend on
30 the judgment of the practitioner. However, suitable
dosage ranges are of the order of several hundred
micrograms active ingredient per vaccination. Suitable
regimes for initial administration and booster shots are
also variable, but are typified by an initial
35 administration followed by subsequent inoculations or
other administrations.

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The manner of application may be varied widely. Any of the conventional methods for administration of a vaccine are applicable. These are believed to include oral application on a solid physiologically acceptable base or in a physiologically acceptable dispersion, parenterally, by injection or the like. The dosage of the vaccine will depend on the route of administration and will vary according to the size of the host.

Various methods of achieving adjuvant effect for the vaccine includes use of agents such as aluminum hydroxide or phosphate (alum), commonly used as 0.05 to 0.1 percent solution in phosphate buffered saline, admixture with synthetic polymers of sugars (Carbopol) used as 0.25 percent solution, aggregation of the protein in the vaccine by heat treatment with temperatures ranging between 70° to 101°C for 30 second to 2 minute periods respectively. Aggregation by reactivating with pepsin treated (Fab) antibodies to albumin, mixture with bacterial cells such as *C. parvum* or endotoxins or lipopolysaccharide components of gram-negative bacteria, emulsion in physiologically acceptable oil vehicles such as mannide mono-oleate (Aracel A) or emulsion with 20 percent solution of a perfluorocarbon (Fluosol-DA) used as a block substitute may also be employed.

In many instances, it will be desirable to have multiple administrations of the vaccine, usually not exceeding six vaccinations, more usually not exceeding four vaccinations and preferably one or more, usually at least about three vaccinations. The vaccinations will normally be at from two to twelve week intervals, more usually from three to five week intervals. Periodic boosters at intervals of 1-5 years, usually three years, will be desirable to maintain protective levels of the antibodies. The course of the immunization may be

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followed by assays for antibodies for the supernatant antigens. The assays may be performed by labeling with conventional labels, such as radionuclides, enzymes, fluorescers, and the like. These techniques are well known and may be found in a wide variety of patents, such as U.S. Patent Nos. 3,791,932; 4,174,384 and 3,949,064, as illustrative of these types of assays.

All of the compositions and methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the composition, methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

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5 supplementary to those set forth herein, are specifically incorporated herein by reference.

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W.P.I. Acc. No.: 91-103941/15 - Weisburg, W.G. (1991).

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SEQUENCE LISTING

(1) GENERAL INFORMATION:

5 (i) APPLICANT:

(A) NAME: BOARD OF REGENTS, THE UNIVERSITY OF
TEXAS SYSTEM

(B) STREET: 201 West 7th Street

(C) CITY: Austin

10 (D) STATE: Texas

(E) COUNTRY: United States of America

(F) POSTAL CODE (ZIP): 78701

15 (ii) TITLE OF INVENTION: DIAGNOSTIC TESTS FOR A NEW
SPIROCHETE, BORRELIA
LONESTARI

(iii) NUMBER OF SEQUENCES: 28

20 (iv) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk

(B) COMPUTER: IBM PC compatible

(C) OPERATING SYSTEM: PC-DOS/MS-DOS

25 (D) SOFTWARE: PatentIn Release #1.0, Version
#1.30

(vi) PRIOR APPLICATION DATA:

(A) APPLICATION NUMBER: US 08/437,013

30 (B) FILING DATE: 08-MAY-1995

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

35 (A) LENGTH: 641 base pairs

(B) TYPE: nucleic acid

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(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

5

ACATATT	CAG	ATGCAGACAG	AGGTTCTATT	CAAATTGAAA	TTGAACAACT	TACAGATGAA	60
ATTAACAGAG	TTGCTGATCA	GGCTCAATAC	AACCAGATGC	ATATGTTATC	TAACAAATCA		120
TCTGCTCAAA	ATGTAAAAAC	TGCTGAAGAG	CTTGGAATGC	AACCTGCAAA	AATTAATACA		180
CCAGCATCAC	TAACTGGAGC	ACAAGCTTCA	TGGACATTGA	GAGTTCAGGT	AGGTGCAAAAT		240
CAGGATGAAG	CAATTGCTGT	TAATATTTTC	TCAACTAATG	TTGCAAAATCT	TTTTTGGTGGA		300
GAAGGTGTTT	C	AAGCGGCTCC	AGCTCAAGAG	GGTGCACAAC	AGGAGGGAGT	TCAACCAGCT	360
CCAGCTCAAG	GTGGGATTAG	CTCTCCAATT	AATGTTACAA	CTGCTATTGA	TGCTAATGCA		420
TCGCTTACAA	AGATTGAAGA	TGCTATTAGA	ATGGTAACTG	ATCAAAAGAGC	AAATCTTGGT		480
GCTTTCCAAA	ATAGACTTGA	GTCTGTTTAA	GCTAGCACAG	ATTATGCTAT	TGAAAAACTTA		540

15

20

AAAGCGTCTT ATGCTCAAAAT TAAAGATGCA ATAATGACAG ATGAAATTGT AGCATCTACA 600
ACCAACAGTA TTTTGACACA ATCTGCAATG GCTATGATTG C 641

5

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 213 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

10

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

15

Thr Tyr Ser Asp Ala Asp Arg Gly Ser Ile Gln Ile Glu Ile Glu Gln
1 5 10 15

Leu Thr Asp Glu Ile Asn Arg Val Ala Asp Gln Ala Gln Tyr Asn Gln
20 25 30

Met His Met Leu Ser Asn Lys Ser Ser Ala Gln Asn Val Lys Thr Ala
35 40 45

20

Glu Glu Leu Gly Met Gln Pro Ala Lys Ile Asn Thr Pro Ala Ser Leu
 50 55 60
 Thr Gly Ala Gln Ala Ser Trp Thr Leu Arg Val Gln Val Gly Ala Asn
 65 70 75 80
 Gln Asp Glu Ala Ile Ala Val Asn Ile Phe Ser Thr Asn Val Ala Asn
 85 90 95
 Leu Phe Gly Gly Glu Gly Val Gln Ala Ala Pro Ala Gln Glu Gly Ala
 100 105 110
 Gln Gln Glu Gly Val Gln Pro Ala Pro Ala Gln Gly Gly Ile Ser Ser
 115 120 125
 Pro Ile Asn Val Thr Thr Ala Ile Asp Ala Asn Ala Ser Leu Thr Lys
 130 135 140
 Ile Glu Asp Ala Ile Arg Met Val Thr Asp Gln Arg Ala Asn Leu Gly
 145 150 155 160
 Ala Phe Gln Asn Arg Leu Glu Ser Val Lys Ala Ser Thr Asp Tyr Ala
 165 170 175

Ile Glu Asn Leu Lys Ala Ser Tyr Ala Gln Ile Lys Asp Ala Ile Met
180 185 190

Thr Asp Glu Ile Val Ala Ser Thr Thr Asn Ser Ile Leu Thr Gln Ser
195 200 205

Ala Met Ala Met Ile
210

10

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1336 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

15

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

20

CTGGCAGTGC GTCTTAAGCA TGCAAGTCAG ACGGAATGTA GTAATACATTT CAGTGGCGAA 60

CGGGTGAGTA ACGCGTGGAT AATCTGCCTA CGAGA'GGGG ATAAC TATTA GAAATAATAG 120

CTAATACCGA ATAAAGTCAA TTGAGTTGTT AGTTGATGAA AGGAAGCCTT TAAAGCTTCG 180
CTTGTAGATG AGTCTGCGTC TTATTAGCTA GTTGGTAGGG TAAGAGCCTA CCAAGGCTAT 240
5 GATAAGTAAC CGGCCTGAGA GGGTGATCGG TCACACTGGA ACTGAGATAC GGTCCAGACT 300
CCTACGGGAG GCAGCAGCTA AGAATCTTCC GCAATGGGCG AAAGCCTGAC GGAGCGACAC 360
TGCGTGAACG AAGAAGGTCG AAAGATTGTA AAGTTCTTTT ATAAATGAGG AATAAGCTTT 420
10 GTAGGAAATG ACAAGGTGAT GACGTTAATT TATGAATAAG CCCC GGCTAA TTACGTGCCA 480
GCAGCCGCG TAATACGTAA GGGCGGAGCG TTGTTCCGGA TCATTGGGCG TAAAGGGTGA 540
15 GTAGCGGGAT ATGTAAGTCT ATGTGTAAAA TACCACGGCT CAACTGTGGA ACTATGCTAG 600
AAACTGCATG ACTAGAGTCT GATAGGGGAA GTTAGAATTC CTGGTGTAAAG GGTGGAATCT 660
GTTGATATCA GGAAGAATAC CAGAGGCGAA AGCGAACCTC TAGGTCAAGA CTGACGCTGA 720
GTCACGAAAG CGTAGGGAGC AAACAGGATT AGATACCCCTG GTAGTCTACG CTGTAAACGA 780
TGCACACTTG GTGTTAATCG AAAGGTTAGT ACCGAAGCTA ACGTGTTAAG TGTGCCGCCT 840
20

GGGGAGTATG CTCGCAAGAG TGAAGTCAA AGGAATTGAC GGGGGCCCGC ACAAGCGGTG 900

GAGCATGTGG TTTAATTCTGA TGATACGCGA GGAACCTTAC CAGGGCTTGA CATATACAGG 960

5 ATATAGTTAG AGATAACTAC TCTCCGTTTG GGGTCTGTAT ACAGGTGCTG CATGGTTGTC 1020

GTCAGCTCGT GCTGTGAGGT GTTGGGTTAA GTCCCGCAAC GAGCGCAACC CTTGTTGTCT 1080

GTTACCAGCA TGTAAGATG GGGACTCAGA CGAGACTGCC GGTGATAAGC CGGAGGAAGG 1140

10 TGAGGATGAC GTCAAATCAT CATGGCCCTT ATGTCCTGGG CTACACACGT GCTACAATGG 1200

CCTGTACAAA GCGATGCGAA ACAGTGATGT GAAGCAAAAC GCATAAAGCA GGTCTCAGTC 1260

15 CAGATTGAAG TCTGAAACTC GACTTCATGA AGTTGGAATC GCTAGTAA'PC GTATATCAGA 1320

ATGATACGGT GAATAC 1336

20 (2) INFORMATION FOR SEQ ID NO:4:

(1) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 330 base pairs

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- (B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

5 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

AACTGCTGAA GAGCTTGGAA TGCAACCTGC AAAAATTAAT ACACCAGCAT CACTAACTGG 60
AGCACAAGCT TCATGGACAT TGAGAGTTCA GGTAGGTGCA AATCAGGATG AAGCAATTGC 120
TGTTAATATT TTCTCAACTA ATGTTGCAA TCTTTTGGT GGAGAAGGTG TTCAAGCGGC 180
TCCAGCTCAA GAGGTGCAC AACAGGAGG AGTTCAACCA GCTCCAGCTC AAGGTGGGAT 240
TAGCTCTCCA ATTAATGTTA CAACTGCTAT TGATGCTAAT GCATCGCTTA CAAAGATTGA 300
AGATGCTATT AGAATGGTAA CTGATCAAAG 330

20 (2) INFORMATION FOR SEQ ID NO:5:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 4 amino acids

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- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

5 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

Gly Val Gln Ala
1

10

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 9 base pairs
- 15 (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

20

TCTGCTCAA

9

(2) INFORMATION FOR SEQ ID NO:7:

25

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 12 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- 30 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

GGTGTTCAAG CG

12

35

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(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- 5 (A) LENGTH: 9 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

10

GTTCAACCA

9

(2) INFORMATION FOR SEQ ID NO:9:

15

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
20 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

AACAGCTGAA GAGCTTGGAA TG

22

25

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

- 30 (A) LENGTH: 26 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

35

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

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CGATAATCTT ACTATTCACT AGTTTC

26

(2) INFORMATION FOR SEQ ID NO:11:

5

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 24 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

10

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

ACATATTCAG ATGCAGACAG AGGT

24

15

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:

20

(A) LENGTH: 24 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

25

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

TGTTAGACGT TACCGTTACT AACG

24

30

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs

(B) TYPE: nucleic acid

35

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

- 92 -

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

CTGGCAGTGC GTCTTAAGCA

20

5

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

- 10 (A) LENGTH: 25 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

15

CATATAGTCT TACTATGCCA CTTAG

25

(2) INFORMATION FOR SEQ ID NO:15:

20

(i) SEQUENCE CHARACTERISTICS:

- 25 (A) LENGTH: 31 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

Leu Arg Val Gln Val Gly Ala Asn Gln Asp Glu Ala Ile Ala Val Asn
1 5 10 15

5

Ile Phe Ser Thr Asn Val Ala Asn Leu Phe Gly Gly Glu Gly Val
20 25 30

10 (2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 16 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS:

(D) TOPOLOGY: linear

15

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

Gln Ala Ala Pro Ala Gln Glu Gly Ala Gln Gln Glu Gly Val Gln Pro
1 5 10 15

20

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

Ala Pro Ala Gln Gly Ile Ser Ser Pro Ile Asn Val Thr Thr Ala
1 5 10 15

Ile Asp Ala Asn

20

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 7 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:

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(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

5 Ala Ala Pro Ala Pro Ala Ala
 1 5

(2) INFORMATION FOR SEQ ID NO:19:

10

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 7 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS:
15 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

20 Ala Thr Pro Ala Pro Val Ala
 1 5

(2) INFORMATION FOR SEQ ID NO:20:

25 (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 7 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS:
 (D) TOPOLOGY: linear

30

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

35 Ala Ala Pro Ala Pro Ala Ser
 1 5

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(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:

- 5 (A) LENGTH: 4 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

10

Ala Gln Ala Ala

1

15 (2) INFORMATION FOR SEQ ID NO:22:

(i) SEQUENCE CHARACTERISTICS:

- 20 (A) LENGTH: 5 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

25

Pro Thr Pro Ala Thr

1

5

(2) INFORMATION FOR SEQ ID--NO:23:

30

(i) SEQUENCE CHARACTERISTICS:

- 35 (A) LENGTH: 5 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

Pro Ala Pro Val Thr

1 5

5

(2) INFORMATION FOR SEQ ID NO:24:

(i) SEQUENCE CHARACTERISTICS:

- 10 (A) LENGTH: 4 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

15 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

Ala Gln Thr Ala

1

20

(2) INFORMATION FOR SEQ ID NO:25:

(i) SEQUENCE CHARACTERISTICS:

- 25 (A) LENGTH: 5 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

30

Pro Ala Pro Ala Thr

1 5

35 (2) INFORMATION FOR SEQ ID NO:26:

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(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 709 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

5

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:26:

10 AACAAACAACC TCGGGATCGA GGAAGGATT TCAGAATTCA CATATTCAGA TGCAGACAGA 60
GGTTCCTATTC AAATTGAAAT TGAACAACTT ACAGATGAAA TTAACAGAGT TGCTGATCAG 120
GCTCAATACA ACCAGATGCA TATGTTATCT AACAAATCAT CTGCTCAAAA TGTAAAAACT 180
15 GCTGAAGAGC TTGGAATGCA ACCTGCAAAA ATTAATACAC CAGCATCACT AACTGGAGCA 240
CAAGCTTCAT GGACATTGAG AGTTCAGGTA GGTGCAAATC AGGATGAAGC AATTGCTGTT 300
AATATTTTCT CAACTAATGT TGCAAATCTT TTTGGTGGAG AAGGTGTTCA AGCGGCTCCA 360
20 GCTCAAGAGG GTGCACAACA GGAAGGAGTT CAACCAGCTC CAGCTCAAGG TGGGATTAGC 420
TCTCCAAATTA ATGTTACAAC TGCTATTGAT GCTAATGCAT CGCTTACAAA GATTGAAGAT 480

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GCTATTAGAA TGGTAACTGA TCAAAGAGCA AATCTTGGTG CTTTCCAAA TAGACTTGAG 540
TCTGTTAAAG CTAGCACAGA TTATGCTATT GAAAACTTAA AAGCGTCTTA TGCTCAAATT 600
5 AAAGATGCAA TAATGACAGA TGAATTTGTA GCATCTACAA CCAACAGTAT TTTGACACAA 660
TCTGCAATGG CTATGATTGC AGTCTAGAGT CGACCTGCAG GCAAGCTTG 709

10 (2) INFORMATION FOR SEQ ID NO:27:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 4 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

15

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:27:

20 Ile Ser Glu Phe

1

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(2) INFORMATION FOR SEQ ID NO:28:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 641 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:28:

10

```
ACATATTTCAG ATGCAGACAG AGGTTCTATT CAAATTGAAA TTGAACAACT TACAGATGAA 60
ATTAAACAGAG TTGCTGATCA GGCTCAATAC AACCAGATGC ATATGTTATC TAACAAATCA 120
TCTGCTCAA ATGTAAAAAC TGCTGAAGAG CTTGGAATGC AACCTGC AAA AATTAATACA 180
CCAGCATCAC TAACTGGAGC ACAAGCTTCA TGGACATTGA GAGTTCAGGT AGGTGCAAAAT 240
CAGGATGAAG CAATTGCTGT TAATATTTTC TCAACTAATG TTGCAAAATCT TT'TTGGTGGA 300
GAAGGTGTTT AAGCGGCTCC AGCTCAAGAG GGTGCACAAC AGGAAGGAGT TCAACCCAGCT 360
CCAGCTCAAG GTGGGATTAG CTCTCCAATT AATGTTACAA CTGCTATTGA TGCTAATGCA 420
```

20

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TCGCTTACAA AGATTGAAGA TGCTATTAGA ATGGTAACTG ATCAAAGAGC AAATCTTGGT 480

GCTTTCCAAA ATAGACTTGA GTCTGTTAAA GCTAGCACAG ATTATGCTAT TGA AAAACTTA 540

5 AAAGCGTCTT ATGCTCAAAT TAAAGATGCA ATAATGACAG ATGAAATTGT AGCATCTACA 600

ACCAACAGTA TTTTGACACA ATCTGCAATG GCTATGATTG C 641

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CLAIMS:

1. A purified DNA segment that encodes a *B. lonestari*
5 sp. nov.-specific biological component.
2. The DNA segment of claim 1, wherein said DNA segment
10 encodes a flagellin protein.
3. The DNA segment of claim 2, wherein said DNA segment
encodes a flagellin protein comprising a contiguous amino
15 acid sequence from SEQ ID NO:2.
4. The DNA segment of claim 2, comprising a contiguous
nucleic acid sequence from SEQ ID NO:1, SEQ ID NO:4 or
20 SEQ ID NO:26.
5. The DNA segment of claim 4, comprising a contiguous
nucleic acid sequence from SEQ ID NO:1.
- 25 6. The DNA segment of claim 1, wherein said DNA segment
encodes an rRNA component.
- 30 7. The DNA segment of claim 4, comprising a contiguous
nucleic acid sequence from SEQ ID NO:3.
8. The DNA segment of claim 1, comprising at least one
35 *B. lonestari* sp. nov.-specific nucleotide or species-

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specific combination of nucleotides from Table 2 or Table 3, or a complement to said DNA segment.

5 9. A purified nucleic acid molecule comprising a nucleotide sequence of about 12 to about 709 nucleotides that encodes a *B. lonestari* sp. nov.-specific flagellin protein or peptide having at least one *B. lonestari* sp. nov.-specific amino acid or species-specific combination
10 of amino acids from Table 1, or a complement of said nucleic acid molecule.

10. The nucleic acid molecule of claim 9 wherein the
15 nucleotide sequence comprises from about 12 to about 641 nucleotides.

11. The nucleic acid molecule of claim 10 wherein the
20 nucleotide sequence has from about 12 to about 330 nucleotides.

12. The nucleic acid molecule of claim 9 wherein the
25 encoded flagellin peptide comprises a *B. lonestari* sp. nov. specific amino acid at position 24, 65, 67, 90, 91, 92, 99, 103, 119, 126, 127, 136, 140, 174, or 191 of SEQ ID NO:2.

30 13. The nucleic acid molecule of claim 9 wherein the encoded flagellin peptide comprises at least one *B. lonestari* sp. nov.-specific combination of amino acids from Table 1.

35

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14. The nucleic acid molecule of claim 9 wherein the encoded flagellin peptide includes *B. lonestari* sp. nov.-specific amino acids at and flanking positions 90-92, 103-108, 119-127, 136-144, or 171-174 of SEQ ID NO:2.

5

15. The nucleic acid molecule of claim 9 comprising the sequence GGTGTTCAAGCG (SEQ ID NO:7).

10

16. The nucleic acid molecule of claim 9 comprising the sequence GTTCAACCAGCT (SEQ ID NO:8).

15 17. The nucleic acid molecule of claim 9 comprising a contiguous nucleotide sequence from SEQ ID NO:1, SEQ ID NO:4 or SEQ ID NO:26.

20 18. The nucleic acid molecule of claim 17 comprising a contiguous nucleotide sequence from SEQ ID NO:1.

25 19. The nucleic acid molecule of claim 17 comprising a contiguous nucleotide sequence from SEQ ID NO:4.

30 20. The nucleic acid molecule of claim 17 comprising a contiguous nucleotide sequence from SEQ ID NO:26.

35 21. The nucleic acid molecule of claim 9 wherein the nucleotide sequence encodes a protein having an amino acid sequence of SEQ ID NO:2.

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22. A purified nucleic acid molecule comprising a contiguous nucleotide sequence represented in SEQ ID NO:1 or SEQ ID NO:3 having at least one *B. lonestari* sp. nov.-specific nucleotide or species-specific combination of nucleotides from Table 2 or 3, or a complement of said nucleic acid molecule.

23. A recombinant molecule comprising the DNA segment or nucleic acid molecule of any preceding claim.

24. The recombinant molecule of claim 23 wherein the molecule is an expression vector.

25. A host cell comprising the recombinant molecule of claim 23 or claim 24.

26. A purified flagellin protein of *B. lonestari* sp. nov.

27. A purified *B. lonestari* sp. nov.-specific flagellin protein.

28. The flagellin protein of claim 26 or claim 27 comprising a contiguous amino acid sequence from SEQ ID NO:2.

29. The flagellin protein of claim 28 having the sequence of SEQ ID NO:2.

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30. The flagellin protein of claim 27 comprising at least one *B. lonestari* sp. nov.-specific amino acid from Table 1.

5

31. The flagellin protein of claim 27 comprising *B. lonestari* sp. nov.-specific amino acids at and flanking positions 90-92, 103-108, 119-127, 136-144, or 171-174 of SEQ ID NO:2.

10

32. The flagellin protein of claim 27 comprising the sequence Gly Val Gln Ala (SEQ ID NO: 5) or Val Gln Pro.

15

33. A purified peptide or protein comprising an amino acid sequence having about 6 to about 213 amino acids of SEQ ID NO:2 that includes at least one *B. lonestari* sp. nov.-specific amino acid or species-specific combination of amino acids from Table 1.

20

34. The purified peptide or protein of claim 33 comprising a *B. lonestari* sp. nov. specific amino acid is at position 24, 65, 67, 90, 91, 92, 99, 103, 119, 126, 127, 136, 140, 174, or 191 of SEQ ID NO:2.

25

35. The purified peptide or protein of claim 33 defined further as comprising the sequence Gly Val Gln Ala (SEQ ID NO:5) or Val Gln Pro.

30

36. The purified peptide or protein of claim 33 comprising the sequence of SEQ ID NO:15.

35

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37. The purified peptide or protein of claim 33 comprising the sequence of SEQ ID NO:16.

5 38. The purified peptide or protein of claim 33 comprising the sequence of SEQ ID NO:17.

39. A fusion protein comprising the peptide of claim 33.
10

40. The fusion protein of claim 39 comprising a peptide encoded by SEQ ID NO:26.

15 41. A purified *B. lonestari* sp. nov.-specific rRNA component comprising a contiguous nucleotide sequence from, or complementary to, SEQ ID NO:3 and having at least one *B. lonestari* sp. nov.-specific nucleotide or
20 species-specific combination of nucleotides from Table 3.

42. A purified antibody that binds to a *B. lonestari* sp. nov.-specific flagellin protein or peptide.
25

43. Use of a DNA segment comprising an isolated *B. lonestari* sp. nov.-specific gene in the preparation of a recombinant *B. lonestari* sp. nov.-specific biological
30 component.

44. Use of a DNA segment comprising an isolated *B. lonestari* sp. nov.-specific gene in the preparation of
35 a diagnostic formulation for use in identifying *B. lonestari* sp. nov., for diagnosing a Lyme disease-like

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54. A method of detecting *B. lonestari* sp. nov., comprising contacting a sample suspected of containing *B. lonestari* sp. nov nucleic acids with an isolated *B. lonestari* sp. nov-specific nucleic acid segment, or a complement thereof, under conditions effective to allow nucleic acid hybridization, and detecting the hybridized nucleic acids thus formed.

55. The method of claim 54, wherein said isolated nucleic acid segment comprises a contiguous nucleic acid sequence from SEQ ID NO:1, SEQ ID NO:3, SEQ ID NO:4 or SEQ ID NO:26.

56. The method of claim 54, wherein said isolated nucleic acid segment comprises the nucleic acid sequence GGTGTTCAAGCG (SEQ ID NO:7).

57. The method of claim 54, wherein said isolated nucleic acid segment comprises the nucleic acid sequence GTTCAACCAGCT (SEQ ID NO:8).

58. The method of claim 54, comprising the steps of:

(a) contacting the sample nucleic acids with a pair of nucleic acid primers that hybridize to specific sequences from a *B. lonestari* sp. nov nucleic acid sequence, the primers capable of amplifying a *B. lonestari* sp. nov-specific nucleic acid segment when used in conjunction with a polymerase chain reaction;

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(b) conducting a polymerase chain reaction to create *B. lonestari* sp. nov-specific amplification products; and

5 (c) detecting the amplification products thus formed.

59. The method of claim 54, comprising the steps of:

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(a) contacting the sample nucleic acids with a pair of nucleic acid primers that hybridize to sequences from *B. lonestari* sp. nov nucleic acids, the primers capable of amplifying
15 *B. lonestari* sp. nov nucleic acids when used in conjunction with a polymerase chain reaction;

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(b) conducting a polymerase chain reaction to create *B. lonestari* sp. nov amplification products; and

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(c) sequencing the amplification products thus formed to identify the presence of *B. lonestari* sp. nov-specific amplified sequences.

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60. A method of detecting *B. lonestari* sp. nov., comprising testing DNA from a sample suspected of containing *B. lonestari* sp. nov for the presence of a
restriction fragment length polymorphism that is specific
to *B. lonestari* sp. nov.

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61. The method of claim 60, wherein the restriction fragment length polymorphism test comprises digesting DNA with the restriction enzyme *AluI*.

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62. A method for detecting *B. lonestari* sp. nov. in a sample, comprising contacting a sample suspected of containing *B. lonestari* sp. nov. with an antibody that binds to a *B. lonestari* sp. nov.-specific flagellin protein or peptide, under conditions effective to allow the formation of immune complexes, and detecting the immune complexes so formed.
63. A method for detecting an anti-*B. lonestari* sp. nov. antibody or T cell in a sample, comprising contacting a sample suspected of containing said antibody or T cell with a *B. lonestari* sp. nov.-specific flagellin protein, peptide or fusion protein, under conditions effective to allow the formation of antibody-protein or T cell-protein immune complexes, and detecting the immune complexes so formed.
64. A nucleic acid detection kit comprising, in suitable container means, an isolated *B. lonestari* sp. nov.-specific nucleic acid segment and a detection reagent.
65. An immunodetection kit comprising, in suitable container means, an isolated *B. lonestari* sp. nov.-specific flagellin protein or peptide, or a first antibody that binds to a *B. lonestari* sp. nov.-specific flagellin protein or peptide, and an immunodetection reagent.

1/1

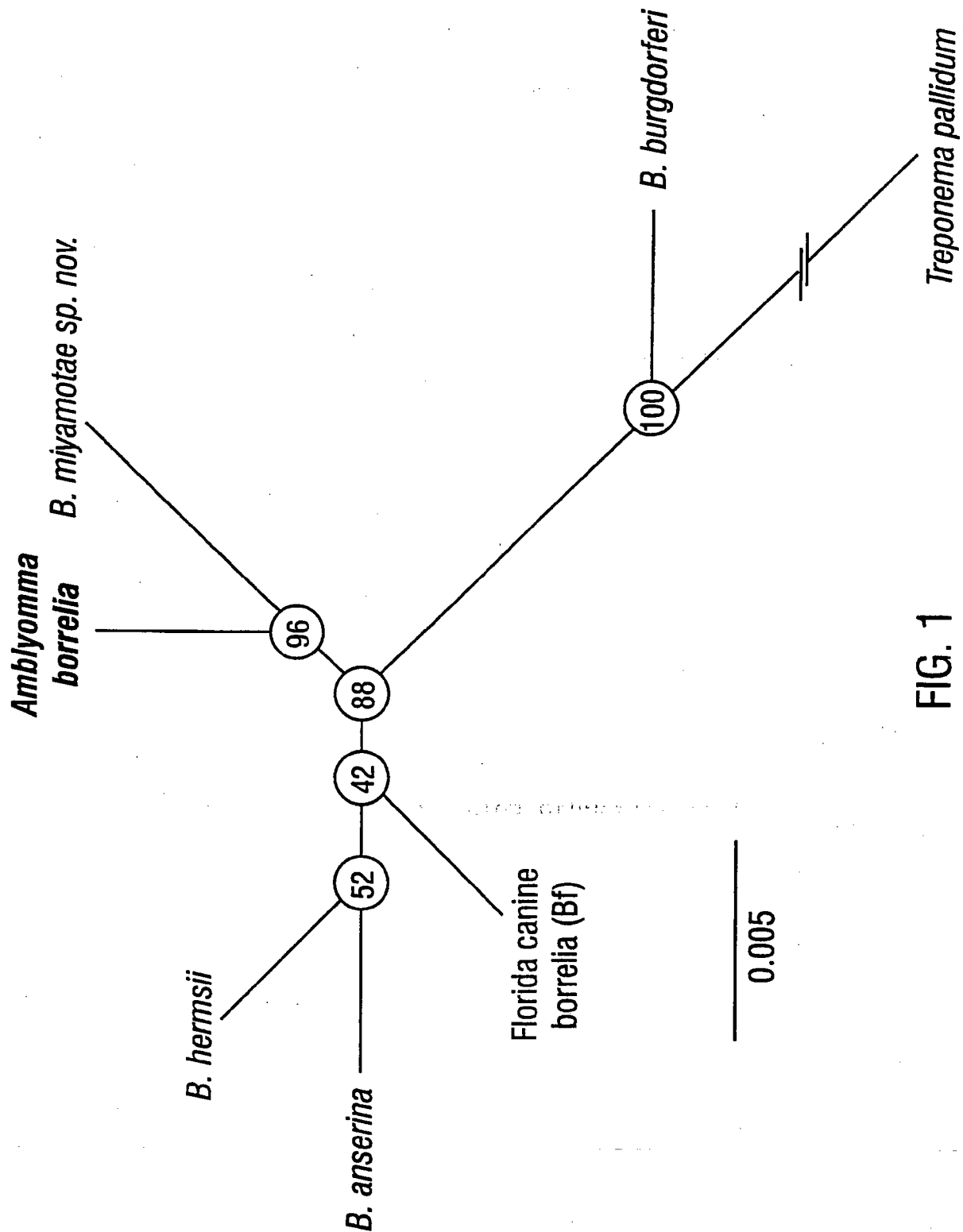


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/06556

A. CLASSIFICATION OF SUBJECT MATTER IPC(6) : A61K 39/02; C07H 21/04; C07K 16/12; C12Q 1/68; G01N 33/569 US CL : Please See Extra Sheet. According to International Patent Classification (IPC) or to both national classification and IPC														
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 424/164.1, 185.1, 190.1, 234.1; 435/6, 7.32, 91.2; 530/388.4; 536/23.7, 24.3, 24.32, 24.33; 935/3, 12, 77 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) APS, CA, MEDLINE, DERWENT search terms: borrelia, lonestari, flagellin, ribosomal RNA, rRNA, gene#, antibod?, protein														
C. DOCUMENTS CONSIDERED TO BE RELEVANT														
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.												
A	NOPPA et al. Expression of the flagellin gene in Borrelia is controlled by an alternative δ factor. Microbiology. 1995, Vol. 141, pages 85-93.	1-5, 7-25, 43-47, 54-61, 64												
A	US 5,283,175 A (WEAVER ET AL) 01 February 1994.	1-5, 7-25, 43-47, 54-61, 64												
A,P	FUKUNAGA et al. Genetic and Phenotypic Analysis of Borrelia miyamotoi sp. nov., Isolated from the Ixodid Tick Ixodes persulcatus, the Vector for Lyme Disease in Japan. International Journal of Systematic Bacteriology. October 1995, Vol. 45, No. 4, pages 804-810.	1, 6, 22-25, 41, 43-47, 53-61												
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.														
<table border="0"> <tr> <td>* Special categories of cited documents:</td> <td>*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>*A* document defining the general state of the art which is not considered to be of particular relevance</td> <td>*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>*E* earlier document published on or after the international filing date</td> <td>*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>*Z* document member of the same patent family</td> </tr> <tr> <td>*O* document referring to an oral disclosure, use, exhibition or other means</td> <td></td> </tr> <tr> <td>*P* document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table>			* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	*E* earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z* document member of the same patent family	*O* document referring to an oral disclosure, use, exhibition or other means		*P* document published prior to the international filing date but later than the priority date claimed	
* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention													
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone													
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art													
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z* document member of the same patent family													
O document referring to an oral disclosure, use, exhibition or other means														
P document published prior to the international filing date but later than the priority date claimed														
Date of the actual completion of the international search 23 JULY 1996		Date of mailing of the international search report 27 AUG 1996												
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-4242		Authorized officer PRASAD MURTHY Telephone No. (703) 308-7544												

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/06556

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	MARCONI et al. Phylogenetic Analysis of the Genus Borrelia: a Comparison of North American and European Isolates of Borrelia burgdorferi. Journal of Bacteriology. January 1992, Vol. 174, No. 1, pages 241-244.	1, 6, 22-25, 41, 43-47, 53-61
A	HANSEN et al. Measurement of Antibodies to the Borrelia burgdorferi Flagellum Improves Serodiagnosis in Lyme Disease. Journal of Clinical Microbiology. February 1988, Vol. 26, No. 2, pages 338-346.	26-40, 42, 48-52, 62-63, 65
A	BARBOUR et al. A Borrelia-Specific Monoclonal Antibody Binds to a Flagellar Epitope. Infection and Immunity. May 1986, Vol. 52, No. 5, pages 549-554.	26-40, 42, 48-52, 62-63, 65

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/06556

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☒ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/06556

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

424/164.1, 185.1, 190.1, 234.1; 435/6, 7.32, 91.2; 530/388.4; 536/23.7, 24.3, 24.32, 24.33; 935/3, 12, 77

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

Group I, claim(s) 1-25, 41 and 43, drawn to nucleic acid segments encoding *B. lonestari* sp. nov-specific biological components, vectors and transformed host cells thereof and method of using said nucleic acid segments to make protein.
Group II, claim(s) 44, 46-47, 53-61 and 64, drawn to a second method of use (diagnostic) of the nucleic acid segments of I.

Group III, claim(s) 45, drawn to a third method of use (therapeutic) of the nucleic acid segments of I.

Group IV, claim(s) 26-40 and 42, drawn to *B. lonestari* sp. nov-specific purified protein/peptide and antibody specific for the same

Group V, claim(s) 48, drawn to a first method of use of the invention of IV.

Group VI, claim(s) 49, 63 and 65, drawn to a second method of use of the invention of IV.

Group VII, claim(s) 50, drawn to a third method of use of the invention of IV.

Group VIII, claim(s) 51 and 62, drawn to a fourth method of use of the invention of IV.

Group IX, claim(s) 52, drawn to a fifth method of use of the invention of IV.

The inventions listed as Groups I and IV do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention is nucleic acid while the special technical feature of the Group II invention is protein. In chemical structure, the DNA of Group I are comprised of nucleotides and the proteins of Group II are comprised of amino acids. Since the special technical feature of the Group I invention is not present in the Group IV claims and the special technical feature of the Group II invention is not present in the Group I claims, unity of invention is lacking. Additionally, Groups II, III, and V-IX are drawn to multiple, distinct methods beyond the method of use included in Group I and are deemed additional inventions. See PCT Article 17(3)(a) and 37 CFR 1.475(d).